Environment Canada Environnement Canada

2022993I DEST PVM EXCH COPY 03
TD 171.5.C3 R43
VOL ISS 84-07
REGIONAL PROGRAM REPORT (CANADA. EN
VIRONMENTAL PROTECTION SERVICE. PAC
IFIC REGION)

Environment Canada

Environnement Canada

Environmental Protection Service

Service de la protection de l'environnement

ENVIRONMENTAL PROTECTION BRANCH

Environmental Protection Service

Pacific Region

ANNOTATED BIBLIOGRAPHY ON REMOTE SENSING OF ENVIRONMENTAL POLLUTION

Regional Program Report 84-07

By

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Federal N.E.E.D. Program - Environmental Assessment

1984

ABSTRACT

An annotated bibliography of literature on remote sensing has been organized as it applies to the major areas of environmental pollution. Documents listed are accompanied by an abstract enabling the determination of appropriate methodology for specific measures of environmental pollution; the majority are quoted directly from the sources.

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INTRODUCTION

Development of remote sensing technology has stimulated investigation of its many uses in evaluating environmental problems. Volumes of information have been produced during the last decade and investigations continue. An annotated bibliography has been organized to provide ready access to this information.

The bibliography comprises two main sections: specific applications, which are ordered by industry and by polluting parameter, and the general reference section, which is oriented to methodologies and investigations of their utility. In the specific applications, tools and techniques used for detecting, identifying, tracing and quantifying activities in observations from airborne and spaceborne platforms have been detailed. Studies and investigations carried out relating to these applications, using different techniques, have been included. Many reports incorporate comparison of data from site collections with interpretation of remotely gathered information.

In the general references (applications and sensor methodology), the papers are classified as review papers or management/programs. Both are found informative and useful to any related application that was specified in the first section. Generally, documents discuss the utilization of remote sensing for environmental pollution, which includes description of the system being developed or used, evaluation of comparable methods, and make recommendations for use.

In awareness of increasing scope and content, this bibliography has been designed to allow expansion for new topics and additional documents at a later period.

Most of the papers are available from Canada Centre for Remote Sensing (CCRS) and these have been cited with the CCRS numbers. Copies of documents with CCRS numbers can be requested from the following address:

The Librarian
Applications Department Division
Canada Centre for Remote Sensing
Department of Energy, Mines & Resources
2464 Sheffield Road
Ottawa, Ontario
K1A 0Y7
Canada

SECTION I

SPECIFIC APPLICATIONS

1.1.0. REMOTE SENSING IN PETROLEUM INDUSTRIES

1.1.1. Airborne Remote Sensing

- Fluorescence Spectroscopy and Raman Spectroscopy
- Infrared Imagery
- Luminescence Method
- Microwave Radiometry
- Multispectral Photography and Low Light Level Television
- Radar System

1.1.2. Satellite Data

1.1.3. Studies and Investigations

1.1.4. Remote Sensing of Oil Pollution - Current Status in:

- United States
- Canada
- France

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Fluorescence Spectroscopy and Raman Spectroscopy

Barringer, A.R./Davies, J.H./Dick, R.

Development of an Airborne Laser Fluorosensor for Oil and Water Pollution Monitoring

Joint Conference on Sensing of Environmental Pollutants, 4th, New Orleans, Louisiana, 1977, p.778

American Chemical Society

Barringer Research Ltd., 304 Carlingview Drive, Rexdale, Ontario M9W 5G2
November 1977

CCRS No. 1007054

Barringer Research has recently developed an airborne laser fluorosensor (LF) for the Canada Centre for Remote Sensing which is to be installed in the CCRS DC-3 aircraft. The instrument utilizes a 1 MW pulsed nitrogen laser (337.1 nm, 4 nsec. pulsed width, 100 pps repetition rate) fluorescence in targets on the water from an altitude of 1,000 to 2,000 feet. The fluorescent return signal is detected by a range gated spectrum analyzer. Signal noise from solar background is minimized by time gating the detector in synchronization with the backscattered radiation. This technique permits the system to be operated in full daylight.

The induced fluorescence signal from each laser pulse is resolved into 16 spectral channels (each of 20 nm nominal width, ranging from 380 to 700 nm) and 2 temporal channels (broad red and blue bands).

The temporal channels deduce the target fluorescence decay time by a real time deconvolution technique. A dedicated microcomputer formats the raw data for a digital tape recorder and also generates a message video display in real time. The major applications of the instrument include oil spill classification, water pollution monitoring and hydrological studies.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Fluorescence Spectroscopy and Raman Spectroscopy

Bristow, M.P.F.

Airborne Monitoring of Surface Water Pollutants by Fluorescence Spectroscopy

Remote Sensing of Environment Vol.7, No.2, April 1978, p.105

Canada Centre for Remote Sensing, Limebanks Road, Ottawa, Ontario K1A 0Y7
April 1978, 23 pages

CCRS No. 1015812

Fluorescence profiles of a controlled oil spill and of the settling ponds and effluent channel near Canadian Int. Paper Co. (Hawkesbury, Ontario) were recorded with an airborne laser fluorosensor by the Canada Centre for Remote Sensing (Ottawa). A pulsed UV laser was used as the excitation source in conjunction with a telescope receiver and photomultiplier detector. The complete system, including power supplies and monitoring and recording equipment was installed and flown on a Canadian Forces DC-3 aircraft. The fluorescence profiles exhibited excellent signal-to-noise ratios and ground resolution, thereby providing good discrimination between targets of different fluorescence quantum efficiency.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Fluorescence Spectroscopy and Raman Spectroscopy

Elderling H.G./Horing, A.W./Webb, W.A.

Detection and Identification of Oil Spills by Remote Fluorometric Systems

Baird-Atomic, Inc., 125 Middlesex Turnpike, Bedford, MA 01730

Department of Transportation, U.S. Coast Guard, Office of Research and Development, Washington, D.C. 20593
September 1974

CCRS No. 1018062

An Oil Spill Surveillance System based on remote measurement of petroleum oil fluorescence was designed built and tested. This system is capable of oil spill detection and oil classification in a commercial harbour environment at a range in excess of 100 meters during hours of darkness. The system functions at viewing angles varying from vertical to within 10 degrees of the horizon and may be programmed for area detection scanning.

Fluorescence spectra of a range of oils are presented including corrected spectra presented in a two-dimensional format. General classification of oil type through fluorescence measurement is discussed. A method for the estimation of film thickness from remote fluorescence measurements is described and a polarization technique for discriminating between natural marine and oil fluorescence is presented.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Fluorescence Spectroscopy and Raman Spectroscopy

Fantasia, J.F./Ingrao, H.C.

The Development of an Experimental Airborne Laser Remote Sensor for Oil Detection and Classification in Spills

U.S. Department of Transportation, Transportation Systems Centre, Kendall Square, Cambridge, MA 02142

U.S. Department of Transportation, U.S. Coast Guard, Office of Research and Development. Washington, D.C. 20590
February 1975

CCRS No. 1018063

Use of laser-excited oil fluorescence as a means of detecting and classifying oils and spills in the marine environment was undertaken at the DOT/Transportation System Centre. The study consisted of an analysis of the fluorescence properties of oils and oil slicks on the sea surface, and a theoretical analysis of the remote fluorometry of oil spills. As a result of this study, laboratory and field measurements were undertaken. Laboratory measurements were made of 29 crude and refined oils commonly transported in the marine environment. These measurements were made with a laboratory model of an N_2 laser oil spill remote sensor that was designed and built at TSC and installed at Point Allerton, Hull, Massachusetts. Results of these measurements showed that, under certain conditions, oil spills can be detected and classified in the marine environment. A program was undertaken for further development of this technique. As part of the program the Experimental Remote Oil Detection and Classification (ERODAC) system was developed. After laboratory tests the ERODAC was field tested onboard a helicopter. The field tests showed that the ERODAC, under certain conditions, is capable of remotely detecting and classifying oils in spills.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Fluorescence Spectroscopy and Raman Spectroscopy

Houston, W.R.

A Review of the Potential of the Laser Fluorosensor for the Classification of Oil Spills

Barringer Research Ltd., 304 Carlingview Drive, Rexdale, Ontario M9W 5G2
xxx 1975, 52 pages

CCRS No. 1008626

This paper attempts to compile the knowledge generated to date which is relevant to the laser fluorosensor role in classifying oil spills on water. Where possible, the available data pertaining to excitation at 337.1 nm has been summarized. This wavelength is of particular interest since presently anticipated fluorosensor designs incorporate nitrogen lasers. These are favoured for this application because of their ability to excite many types of compounds, and provide a good fluorescence signal-to-noise ratio for airborne operation in full daylight. Recommendations are made, based on this compilation, regarding selection of operational classification parameters, the classification scheme itself and the development of a comprehensive fluorescence library.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Fluorescence Spectroscopy and Raman Spectroscopy

Measures, R.M./Bristow, M.

The Development of an Airborne Remote Laser Fluorosensor for Use in Oil Pollution Detection and Hydrologic Studies

UTIAS Report No.175

Institute for Aerospace Studies, University of Toronto
December 1971, 35 pages

CCRS No. 1002100

The first phase of a development programme devoted to the exploitation of laser induced fluorescence for environmental sensing has been compared. A prototype laser fluorosensor has been constructed and used to evaluate, in the laboratory, the feasibility of this concept and to explore the potential range of applications. Special attention has been given to assessing the ability of a laser fluorosensor to map the extent of an oil slick, locate the source of lignin sulphonate pollution and monitor the dispersal of a tracer dye for hydrographic users. The preliminary results of our study are very encouraging and lead us to predict that a laser fluorosensor could be used for environmental sensing from an aircraft flying at between 1,000 and 2,000 feet on a 24-hour basis.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Fluorescence Spectroscopy and Raman Spectroscopy

Sato, T. et al

A Method for Remote Detection of Oil Spills Using Laser-Excited Raman Backscattering and Backscattered Fluorescence

IEEE Journal of Oceanic Engineering, Vol. OE-3, No.1, January 1978

Electronical Laboratory, Laser Research Section, Tanashi, Tokyo, Japan January 1978, 4 pages

CCRS No. 1021432

A laser method for the remote detection of oil present as a pollutant in sea water using Raman backscattering and backscattered fluorescence is discussed. The scattering spectra of oils obtained by using a laser Raman spectrometer that employs a CW Argon laser are described. The backscattering spectra of oils obtained by a laser radar technique in the laboratory and the field are also described. Furthermore, theoretical performance of a laser radar with a CW laser or a pulsed laser for the detection of Raman backscattering of kerosene is discussed.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Fluorescence Spectroscopy and Raman Spectroscopy

Sheives, T.C./Rouse, J.W./Mayo, W.T.

Remote Measurements of Water Pollution with a LIDAR Polarimeter Int. Symp.on Remote Sensing of Environment, 9th, Ann Arbor, Michigan, April 15-19, 1974

Environmental Research Institute of Michigan, Ann Arbor, MI 48107

Remote Sensing Centre (Texas A&M University), College Station, April 1974, 14 pages

CCRS No. 1005077

This paper examines a dual polarization laser backscatter system as a method for remote measurements of certain water quality parameters. Analytical models for describing the backscatter from turbid water and oil on turbid water are presented and compared with experimental data. Laser backscatter field measurements from natural waterways are presented and compared with simultaneous ground observations of the water quality parameters: turbidity, suspended solids, and transmittance. The results of this study show that the analytical models appear valid and that the sensor investigated is applicable to remote measurements of these water quality parameters and oil spills on water.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Fluorescence Spectroscopy and Raman Spectroscopy

Villiers de, J.N.

Airborne Detection and Mapping of Oil Spills, Grand Bahamas, February 1973

Canada Centre for Remote Sensing, 2464 Sheffield Road, Ottawa, Ontario, K1A 0Y7

Data Report 73-7
September 1973, 13 pages

CCRS No. 1005299

An airborne exercise is described employing various sensors to investigate their ability to detect and map Louisiana Crude and Naptha Oil spills, both by day and by night.

It is shown that photographic, infra-red scanning and low light level T.V. all have some ability to detect Louisiana; only infra-red scanning detected naptha. None of these sensors could identify the anomalies as oil.

A laser fluorosensor showed promise in detecting oil at night. Further development will be needed to explore the full potential of such a technique.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Infrared Imagery

Estes, J.E./Golomb, B.

Oil Spills: Method for Measuring their Extent on the Sea Surface Science, Vol.169, August 14, 1970, p.676

University of California, Department of Geography, Santa Barbara, CA 93106 August 1970

CCRS No. 1006711

It is difficult to estimate the area affected by an oil spill at sea, the degree of coverage by oil pollutants within the affected area, and the quantity of pollutants involved. Estimates of volumes and flow rates are based on estimated changes in a real extent of the spill. Uncertainties in measurement of area degrade the accuracy of estimating other parameters. To resolve this problem, available stock components have now been assembled into a system that yields repeatable, economical measurement of the areal extent of oil spills at acceptable levels of accuracy. The system comprises overflights with a thermal infrared imaging system, densitometric colour enhancement of the infrared images, and automatic digital planimetry of the areas of specific image densities.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Infrared Imagery

Kennedy, J.M./Wermund, E.G.

Oil Spills, IR and Microwave

American Society of Photogrammetry, Vol.37, No.12
December 1971, pp. 1235-1242

TRW Systems & Remote Sensing, Houston, Texas
December 1971, 8 pages

CCRS No. 1004275

Examples indicate that the utilization of thermal infrared and microwave radiometric data, approached from a systems point of view, are of value to operational groups charged with cleaning up oil pollution in ocean and coastal water environments. In addition, these systems may be used to upgrade and increase the value of theoretical models so that they more nearly agree with field observations. The preliminary findings of this study point to fruitful areas of directed applications research and techniques and should be pursued with vigour and proper governmental funding. This would ultimately result in greatly reduced costs for spill tracking, source identification, determining the terminal destination and determining the efficiency of clean-up operations.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Infrared Imagery

Rambie, G.S./Morgan, R.H./Jones, D.R.

Feasibility of Continous Monitoring for Oil Pollution Across Channels and Rivers

Oil Spill Conference, 1977

Rambie, Inc., Irving, Texas 75061

Environmental Protection Agency, 401 M Street, S.W., Washington, D.C. 20460
xxx 1977, 4 pages

CCRS No. 1014666

Hydrogen-on-water monitors are useful to help control surface water pollution. The bistatic active infrared scanning oil sensor which is described could increase point monitoring (typical of most contemporary monitors) to a narrow area that can be scaled down with consequent improvements in performance.

A modified production model of an active infrared monostatic oil sensor was used in laboratory tests to determine the spectral reflectance signatures of hydrocarbons and water at 3.4 and 3.8 micrometer wavelengths as a function of bistatic angle, with and without water waves. It was found that the signatures of all the hydrocarbons (six different types) were almost identical and uniquely different from water at bistatic angles up to 85 degrees with respect to the water surface normal. Proper operation of the scanning oil sensor requires that water have a wavy surface. The theoretical requirements for waves and the experimental results were in close agreement.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Infrared Imagery

Thomson, K.P./McColl, W.D.

A Remote Sensing Survey of Chedabucto Bay Oil Spill

Environment Canada

Scientific Series No.26

Canada Centre for Inland Waters, Burlington, Ontario, 1972
xxx 1972, 19 pages

CCRS No. 1002737

The effectiveness of the infrared line scanner, a modified Reconofax IV, as a tool for detecting oil spills was tested at the time of the grounding and subsequent break-up of the oil tanker "Arrow" in Chedabucto Bay, Nova Scotia, February 1970. For photographic surveillance of the spill, a variety of film filter combinations were used.

Results indicated that the infrared line scanner is useful only when there is a significant temperature difference between the oil and the water. Identification of oil on infrared imagery would be facilitated by the use of a quantitative line scanner. For simple surveillance, photographic imagery is superior, especially when optimum film filter combinations are used. Photography is limited to daytime observations.

Although either technique can be used to delineate and monitor an oil slick, neither can positively identify oil.

The report includes illustrated examples.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Infrared Imagery

Gross, H.G./Muramoto, M.

Crude and Refined Petroleum Oil Structured Luminescence Signatures Induced by UV Laser or Lamp and their Remote Sensing Applications

Int. Symp. on Remote Sensing of Environment, 9th, Ann Arbor, Michigan, April 15-19, 1974

Environmental Research Institute of Michigan, Ann Arbor, MI 48107

McDonnell Douglas Astronautics Co., Biotechnology and Space Science Subdivision, Huntington Beach, CA 92647
April 1974, 13 pages

CCRS No. 1005080

Design parameters have recently prompted questions whether luminescence emission spectra of petroleum oils, induced by a single wavelength, are single or multiple peaked. Both have been observed by those using UV laser or lamps. Structured luminescence spectra of oils are produced by us with different UV lines from a CW argon ion laser (2573A) and a mercury glow lamp (2537A). Ten virgin crude oils and one refined fuel oil were studied without dilution or containment. "As measured" spectra (S-20 photocathode on quartz window) tend to have one principal peak, with secondary features in the longer and shorter wavelength direction. "Spectral correction" techniques have allowed us to resolve structures with two or more peaks, shifting the more intense peak wavelengths in the red direction. "As measured" peaks range from the near UV to the orarge, whereas "spectrally corrected" peaks range from the near UV to the near IR. It appears feasible to map an oil spill with a simple active system, using as few as four broad-band photometer channels for classifying oil into four categories.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Luminescence Method

Horing, A.W.

Identification, Estimation and Monitoring of Petroleum in Marine Waters by Luminescence Methods

Marine Pollution Monitoring (Petroleum) Symp., Proc., Gaithersburg, MD, May 13-17, 1974

U.S. National Bureau of Standards, Washington, D.C. 20234

U.S. National Bureau of Standards Special Publication No.409, p.135

Baird Atomic Inc., 125 Middlesex Turnpike, Bedford, MA 1730
December 1974, 10 pages

CCRS No. 1011065

It is described in this paper the potential of luminescence methods of analysis for identifying, estimating and monitoring of petroleum in sea water. The origin of molecular luminescence and the luminescence characteristics of some petroleum oils are also discussed.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Microwave Radiometry

Aukland, J.C./Conway, W.H.

Detection of Oil Slick Pollution on Water Surfaces with Microwave Radiometer Systems

Sixth Symp. on Remote Sensing of Environment, Vol.2, p.789, University of Michigan

Microwave Sensor Systems, Inc.
October 1969

CCRS No. 1000760

Examination of the theoretical and experimental body of information that is presently available leads to the conclusion that there are two mechanisms by which the presence of oil on a water surface may be detected. Both of these mechanisms create an apparent temperature anomaly when oil is present. It is the presence of this local anomaly in the relative uniform background of the sea surface that will signify the detection of oil pollution. This paper develops an analytical basis for the mechanisms and presents the results of experimental verification.

The first phenomenon to be considered is localized change in sea state due to the presence of oil pollution. This phenomenon presents very strong signals to microwave radiometers when winds of 6 knots or more are blowing. It is felt that this will be the primary detection mechanism for thin oil films. The second mechanism to be considered is direct change in the emissivity of the water surface due to the presence of oil. This phenomenon is slightly the weaker of the two, but offers the promise of measuring oil thickness. Because of the independence of these two potential detection mechanisms they are described separately.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Microwave Radiometry

C-CORE
Centre for Cold Ocean Resources Engineering
Memorial University of Newfoundland
St. John's, Newfoundland

Microwave Systems for Detecting Oil Slicks in Ice-Infested Waters: Phase II and III

Canada Environment Impact Control Directorate, Ottawa, Ontario K1A OH3

Economic and Technical Review Report, EPS-3-EC-80-3
September 1980, 150 pages

CCRS No. 1026022

Two ice regimes, one corresponding to waves in ice and the other depicting an iceberg, were selected for analysis of the potential of microwave systems for detecting oil in an ice regime. The results obtained from the manual and digital analysis of 4-channel SAR imagery of these regions are presented and discussed in terms of their relevance to the potential of detecting oil pollution in the ice environment through SAR. The digital analysis consisted of generating histograms, statistics, clutter to noise ratios and grey-tone reproduction. The available digital data corresponded to 8-bit digitization of the square-root of the video.

The results indicate that squaring of the available data reproduces the original data more faithfully than the unsquared data. For grey-tone reproduction equal density quantization is more desirable than equal interval quantization. It appears that the likelihood of detecting oil pollution in the ice environment through SAR can be improved and false alarm risk decreased by collecting SAR data with appropriate gain settings so that return from open water areas falls in the middle of the dynamic range of the system. The resulting digital data can be enhanced by using simple techniques, and reproduced through inexpensive graphic recorders.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Microwave Radiometry

Hollinger, J.P./Mennella, R.A.

Oil Spills : Measurements of their Distributions and Volumes by Multifrequency Microwave Radiometry

Science Volume 181, July 6, 1973, p.54

E.O. Hulburt Centre for Space Research, (Naval Research Lab.), Washington DC 20375
July 1973, 4 pages

CCRS No. 1006312

Aircraft-borne multifrequency passive microwave observations of eight marine oil spills revealed that, in all cases, over 90 percent of the oil was confined in a compact region comprising less than 10 percent of the area of the visible slick. These measurements show that microwave radiometry offers a means of measuring the distribution of oil in sea-surface slicks; for locating the thick regions; and for measuring their volumes on an all-weather, day or night, and real time basis.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Microwave Radiometry

Kennedy, J.M./Wermund, E.G.

Oil Spills, IR and Microwave

American Society of Photogrammetry, Vol.37, No.12, December 1971, pp.1235-1242

TRW Systems & Remote Sensing, Houston, Texas
December 1971, 8 pages

CCRS No. 1004275

Examples indicate that the utilization of thermal infrared and microwave radiometric data, approached from a systems point of view, is of value to operational groups charged with cleaning up oil pollution in ocean and coastal water environments. In addition, these systems may be used to upgrade and increase the value of theoretical models so that they more nearly agree with field observations. The preliminary findings of this study point to fruitful areas of directed applications research. These techniques should be pursued with vigour and proper governmental funding. This would ultimately result in greatly reduced costs for spill tracking, source identification, determining the terminal destination and determining the efficiency of clean-up operations.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Microwave Radiometry

Parashar, S. et al

Assessment of SAR for Oil Pollution Surveillance in the Ice Environment

Port and Ocean Engineering Under Artic Conditions (POAC), Conference, Proc., 5th, Trondheim, Norway, August 13-18, 1979, Vol.3, pp.99-123

University of Trondheim, N-7034 Trondheim-Nth., Norway

Remote Applications Inc., P.O. Box 5547, St. John's, Newfoundland A1C 5W4
xxx 1979, 25 pages

CCRS No. 1027332

The utility of radar for oil pollution surveillance in temperate oceans is established to a certain extent but its corresponding ability over ice and ice-infested waters has yet to be demonstrated. A study was undertaken to assess potentials and limitations associated with the use of active microwave sensors for detecting and monitoring oil pollution in the ice environment. It appears the presence of oil in the ice environment is likely to be detected through identification of indirect subtle clues, i.e., changes in texture and tone such as those produced by increased melting of oil covered ice areas in comparison with oil free areas.

As the tonal and textural contrast due to the presence of oil is expected to be subtle, the variability of signatures in the ice environment was investigated and results are presented. Four-channel synthetic aperture radar (SAR) imagery of ice obtained under C-CORE's Project SAR'77 was studied through manual and digital analyses. It appears that simple image enhancement and processing techniques may provide a means for increasing the likelihood of oil spill detection and reducing the false alarm risk. Based on these analyses, the utility of SAR for oil pollution surveillance in the ice environment is assessed and discussed.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Microwave Radiometry

Paraskar, S.K./Roche, C./Worsfold, R.D.

Investigation of the use of Microwave Systems in Detecting and Monitoring Oil Slicks over Ice and Ice-Infested Waters. Phase II and III Reports.

Memorial University, Centre for Cold Ocean Resources Engineering,
St. John's, Newfoundland, A1C 5S7
March 1979, 62 pages

CCRS No. 1021417

Two ice regimes, one corresponding to waves in ice, and the other depicting an iceberg, were selected for further study under the C-CORE AMOP Phase III contract. The results obtained from manual and digital analysis of 4-channel SAR imagery of these regions are presented and discussed in terms of their relevance to the potential of detecting oil pollution in the ice environment through SAR. The digital analysis consisted of generating histograms, statistics, clutter-to-noise ratios and grey-tone reproduction. The available digital data corresponded to 8-bit digitization of the square-root of the video.

The results indicate that squaring of the available data reproduces the original data more faithfully than the unsquared data. For grey-tone reproduction equal density quantization is more desirable than equal interval quantization. It appears that likelihood of detecting oil pollution in the ice environment through SAR can be improved and false alarm risk decreased by collecting SAR data with appropriate gain settings so that return from open water areas falls in the middle of the dynamic range of the system. The resulting digital data can be enhanced by using simple techniques and reproduced through inexpensive graphic recorders.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Multispectral Photography and Low Light Level Television

Multi-Sensor Oil Spill Detection

7th Symposium on Remote Sensing of Environment, Vol.2, p.1045
University of Michigan

Spectram Inc., Los Angeles, California
May 1971, 8 pages

CCRS No. 1000906

The detection and quantization of oil from moving ships at sea are an ever-increasing problem. Maximum spill rates have been established which are enforced by the U.S. Coast Guard. To be effective the enforcement agencies must obtain data and records for presentation as legal evidence in a court of law. Two programs of controlled oil spills have been conducted to determine the feasibility of using certain sensors at different wavelengths for the detection and measurement of oil spills from moving ships. The results of those programs are summarized in this paper as well as recommendations for an all-weather oil pollution surveillance system.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Multispectral Photography and Low Light Level Television

Estes, J.E./Senger, L.W.

The Multispectral Concept as Applied to Marine Oil Spills

Remote Sensing of Environment, Coden : RSEE-A, Vol.2, No.3, October 1972, p.141-163

American Elsevier Publishing Company, Inc., New York

University of California, Sta. Barbara
October 1972

CCRS No. 1002235

The detection and measurement of oil pollution in the marine environment are receiving augmented attention, as the incidence of oil spills increases with a corresponding demand for information to direct clean-up operations and assign legal responsibility. Owing to the complex behaviour of oil on water, its susceptibility to transport and modification forces, and the physico-chemical anomalies associated with its presence, both aerial and surface-based sensors are necessary components of a complete and effective monitoring system. Ultraviolet, thermal infrared, and microwave sensors exhibit capabilities of potential value for oil detection. Radar, in particular, possesses high value for mapping an oil slick's areal extent since it is operative day or night, under even adverse weather conditions. Since remote sensor systems cannot as yet provide accurate information on the type or thickness of an oil slick, complementary data must be collected using surface-based transport. Radiometric, meteorological and oceanographic information are essential for a valid interpretation of remotely sensed data and a more complete analysis of an oil spill situation. Several potentially operational systems for co-ordination of remote sensing and surface data collection systems in monitoring marine oil pollution are discussed. More research is clearly needed to demonstrate the actual feasibility of any given method.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Multispectral Photography and Low Light Level Television

Jensen, R.C.

Application of Multispectral Photography to Monitoring and Evaluation of Water Pollution

A Collection of Technical Papers - Land and Water, Coden IS (Int. Imaging System) AIAA No. 71-1095

International Imaging System, California
November 1971, 35 pages

CCRS No. 1001290

Two study cases on monitoring and evaluation of water pollution are presented in this paper, based on multispectral photographic techniques. In one case investigated - the San Francisco Bay oil spill, the infrared band appears to be of significant use in establishing boundary areas and the dynamics of oil spills. The two bands, IR and Blue, together produce a significant amount of data required for analysis and evaluation of oil spills. In the case of high altitude U-2 photographic coverage of selected water areas around San Francisco Bay it appears that the Red Band tends to produce the most information in relation to flow patterns for sediment transport.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Multispectral Photography and Low Light Level Television

Jones, D./Landers, R./Pressman, A.

Aerial Photographic Application in Support of Oil Spill Clean-Up Control and Prevention

Oil Spill Conf. (Prevention, Behaviour, Control, Clean-Up) Proc., New Orleans, Luisiana, March 8-10, 1977

American Petroleum Inst., 2101 L Street, N.W., Washington DC 20037

U.S. Environmental Protection Agency, 410 M Street, Washington DC 20460
March 1977, 2 pages

CCRS No. 1014660

For several years the Environmental Protection Agency and EPA contractor aircraft have carried out aerial photographic missions, mapping the areal extent of and shoreline contamination from major oil spills in support of clean-up and control operations and environmental damage assessment. In 1975, EPA began a program of aerial photographic overflights of selected onshore oil production, storage and processing facilities to support the compliance monitoring of EPA's oil pollution prevention regulation. This paper describes the aerial mapping program and also discusses specific applications of aerial photography to oil pollution prevention compliance monitoring.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Multispectral Photography and Low Light Level Television

Kondratyev, K. Ya Et al

The application of Spectrometric and Polarization Techniques for Remote Sensing of Oil on Sea Water

Int. Symp. on Remote Sensing of Environment, 9th, Ann Arbor, Michigan
April 15-19, 1974

Environmental Research Inst. of Michigan, Ann Arbor, MI 48107

University of Leningrad, Leningrad, USSR
April 1974, 10 pages

CCRS No. 1005084

The paper presents the results of the investigations made over the water area with the purpose of (a) obtaining complex data on the optical properties of the sea surface polluted by an oil film, and (b) working out recommendations for remote sensing. The apparatus installed on board the helicopter includes a hand-held spectrograph RSS-2, a polarimeter and two cameras operating in four spectral regions. Both the spectrograph and cameras are provided with polarization attachments. The measurements were conducted in the wavelength range of 0.4 to 0.8 nm at heights up to 200 m.

As a result, data have been obtained on spectral brightness distribution and the degree of polarization of the radiative flux at different heading angles relative to the sun and at various viewing angles for the case of clean and polluted sea surfaces. The optimal spectral intervals and polarization regimes which ensure the highest contrast in photographic images of oil films have been determined. A discussion of the results is given.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Multispectral Photography and Low Light Level Television

Lowe, D.S./Hasell, P.G.

Multispectral Sensing of Oil Pollution

6th Symp. on RS of Environmental, Vol.2, p.755, Univ. of Michigan
October 1969, 11 pages

CCRS No. 1000758

The Santa Barbara oil spill offered an excellent opportunity to observe and map large scale oil pollution in a natural setting. The University of Michigan conducted multispectral flights over the slick in early March. Imagery made from selected spectral bands, extending from the ultraviolet through the thermal infrared, are presented. Imagery from an early morning flight shows the slick best contrasted in the UV and thermal infrared and not detectable in the photo-infrared. Analysis of the data has just begun and is continuing.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Multispectral Photography and Low Light Level Television

Millard, J.P./Arvesen, J.C./Lewis, P.I.

Development and Test of Video Systems for Airborne Surveillance of Oil Spills

National Aeronautics and Space Administration, Ames Research Centre, Moffett Field, California
March 1975, 25 pages

N75-27539/6ST

Five video systems - potentially useful for airborne surveillance of oil spills were developed, flight tested and evaluated. The systems are: (1) conventional black and white TV; (2) conventional TV with false colour; (3) differential TV; (4) Phototype Lunar surface TV; and (5) field sequential TV. Wavelength and polarization filtering were utilized in all systems.

Greatly enhanced detection of oil spills, relative to that possible with the unaided eye, was achieved. The most practical video system is a conventional TV camera with Silicone-Diode-Array image tube, filtered with a Corning 7-54 filter and a polarizer oriented with its principal axis in the horizontal direction. Best contrast between oil and water was achieved when winds and sea states were low. The minimum detectable oil film thickness was about 0.1 micrometer.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Multispectral Photography and Low Light Level Television

Reinheimer, C.J./Rudder, C.L./Berrey, J.L.

Aerial Multiband Photographic Detection of Petroleum Spills

American Soc. of Photogrammetry, Fall Conv., Proc., October 11-14, 1972, p.243

American Soc. of Photogrammetry, Falls Church, VA 22044
Contract No. 68-01-0140

McDonnell Douglas Corporation St. Louis, MO 63166
May 1971, 11 Pages

CCRS No. 1004093

Aerial multiband photography was used to locate oil waste spills in refinery areas located adjacent to inland waterways. The photographic images were evaluated as part of an aerial surveillance spill prevention system. The aerial photographs were taken with an array of four 70-mm cameras, employing 50-mm focal length lenses, in a light aircraft at 1500 ft. above ground level. The multiband photographs were obtained by combining each of nine filters with each of three black-and-white films having different spectral enhancements achieved by either suppressing or transmitting the target-reflected radiation. Normal and false colour photographic images were also compared with the black-and-white multiband images to determine the best film/filter combinations for different petroleum products and sites within the refinery compound. The identification of oil and oil waste spills located in the multiband images was confirmed by ground truth teams.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Multispectral Photography and Low Light Level Television

Vizy, K.N.

Detecting and Monitoring Oil Slicks with Aerial Photography

American Soc. of Photogrammetry, Fall Conv., Proc., October 2-5, 1974

American Soc. of Photogrammetry, Falls Church, VA 22044

Eastman Kodak Company, Research Lab., Rochester, NY 14650
October 1973, 28 pages

CCRS No. 1004772

The presence of large quantities of oil on ocean, lake, and river waters has become a major ecological concern. Agencies in charge of detecting and monitoring these oil slicks are looking for more efficient and reliable reconnaissance techniques. The spectral characteristics of oils and waters indicate that aerial photography could be a useful tool in oil-pollution detection.

Photographs of diesel fuel, gasoline, and spent lubricating oil slicks on barrels of Genessee River water in Rochester, New York, were used to define the brightness contrast between these oils and the water. The effects of types of oil, spectral region, and solar altitude on the photography were evaluated statistically,

Significant detection capability was found in the ultraviolet and blue regions of the spectrum, less in the near infrared, and almost none in the green and red. A method for detecting oil slicks by aerial photographic reconnaissance is presented utilizing standard black-and-white aerial film.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Radar System

Guinard, N.W.

The Remote Sensing of Oil Slicks

MS-7, Vol.2, p.1005, May 1971

Naval Research Laboratory, Washington D.C. 20390
May 1971, 19 pages

CCRS No. 1000904

Radar is presently being used by the Naval Research Laboratory to detect the area of coverage of oil spills. The effort is being sponsored by the U.S. Coast Guard. In the first phase of the study two types of measurement programs were conducted. The first was the mapping of the accidental spill produced when the tanker ARROW collided with Cerberus Roc in Chedabucto Bay, Nova Scotia, while the second was conducted over a programmed spill off the California coast. In both cases, imagery was acquired as a function of radar frequency, poloarization and viewing angle by the NRL Four-Frequency Radar System. As a result, both the feasibility and utility of the radar approach has been established and various characteristics of the oil signature have been determined. Experiments are continuing over both programmed and accidental spills to accumulate a data base from which the relationships between image contrast and radar variables, sea state and oil type and thickness can be obtained as well as to acquire operational data which can provide guidance into the development and utilization of the technique.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Radar System

Krishen, K.

Detection of Oil Spills Using a 13.3 GHz Radar Scatterometer

Journal of Geophysical Research, Vol.78, No.12, April 20, 1973, pp.1452-1963

American Geophysical Union, Richmond, VA 232228

Lockheed Elec. Company Inc., Houston Aerospace System Division, Houston Texas 7705
April 1973, 12 pages

CCRS No. 1004266

This paper describes the results of an analysis of 13.3 GHz Single Polarized Scatterometer data collected during NASA/MSC Mission 135, flown on March 16, 1970. Data were gathered over a crude oil spill on the Gulf of Mexico (Test Site 128) off the Mississippi Delta. With the aid of RC-8 camera photographs, the scattering cross section at higher incidence angles (25° to 50°) decreased by 5 db to 10 db in the presence of the oil spill. This was attributed to oil's damping of small gravity and capillary waves. The composite scattering theory and the scatterometer acquired data were used to obtain an expression of radar scattering over ocean surfaces with oil spills. The study demonstrates that the presence and extent of oil spills can be detected using high frequency radar systems.

SECTION 1.1.2. SATELLITE DATA

Dawe, B.R. et al

Satellite Data on the Kurdistan Spill

Remote Applications Inc., P.O. Box 5547, St. John's, Newfoundland, A1C 5W4
xxx 1979

CCRS No. 1027435

On March 15, 1979, the oil tanker "Kurdistan" was damaged by ice and subsequently broke into two section. Approximately 7,000 metric tons of Bunker C oil were spilled into Cabot Strait. At the time, large areas were ice covered and there was ice cover in a number of bays around Cape Breton Island.

An immediate action by the Environmental Protection Services (EPS) and the Canadian Coast Guard was undertaken to track and clean up the spill, and the satellite imagery from the Shoe Cove Satellite Receiving Station (SCSRS) was used to provide information for tracking the oil spill. This included the use of both LANDSAT and TIROS-N data.

The purpose of the study was to analyze the satellite data available from SCSRS and provide immediate information on the disposition and location of any oil slick detected, and to analyze the data after the spill period to determine the requirements for satellite tracking and monitoring of oil spills both in the open ocean and in ice.

SECTION 1.1.2. SATELLITE DATA

Goldman, G.C./Horvath, R.

Oil-Pollution Detection and Monitoring from Space Using ERTS-1

NASA Contract ERIM 193300-68-F, Final Report, June 12, 1972-November 30, 1974

Environmental Research Inst. of Michigan (ERIM), P.O. Box 618, Ann Arbor, MI 48107
July 1975

CCRS No. 2001433

The purpose of this report is to demonstrate the feasibility of using satellite data as a means of monitoring and detecting oil spills in oceanic and estuarine waters.

Three reported spills were investigated using digital-computer-compatible techniques on ERTS-1 data. A spill on the Atlantic Ocean (off Virginia) was studied to develop spectral signatures. Another spill in Oakland Bay, California, was studied by ratioing spectral channels to look for anomalies caused by oil. The final spill, off Southern California, was investigated by looking for anomalous values in each channel separately.

The results of this study indicate that any of these methods might be usable if the spill is large enough to be seen by satellite, if the spill occurs more than a few kilometers off-shore, and if the sky and water are relatively clear. In the case of the Atlantic spill, identification of material was not possible; in the other two cases, the spills could not be detected at all.

ERTS-1 was not considered feasible for this type of work because of its 18-day overpass frequency, its few spectral channels and the extended bandwidths in which it operates.

SECTION 1.1.2. SATELLITE DATA

Goldman, G.C./Horvath, R.

Oil Pollution Detection and Monitoring from Space Using Skylab

Lyndon B. Johnson Space Centre (NASA), Houston, TX 77058

Environmental Research Inst. of Michigan (ERIM), P.O. Box 618, Ann Arbor, MI 48107
November 1975

CCRS No. 2003754

The purpose of the report is to assess the feasibility of using satellite data as a means of monitoring and detecting oil spills on oceanic and estuarine waters.

One suspected spill was investigated by applying photointerpretation and digital computer techniques to Skylab S190B and S192 data. Other analysis techniques are also discussed.

Indications are that any of these techniques might be usable if the spill is large enough to be seen by satellite, if the spill occurs more than a few kilometers offshore, if the sky and water are relatively clear, and if the data quality is good enough to see the small reflectance changes caused by the presence of oil. In the case described in this report, the presence of the suspected spill could not be verified by computer techniques.

Although the Skylab program was not successful in demonstrating its feasibility for monitoring oil pollution, it did clarify many of the drawbacks and operational problems that may be encountered. Monitoring and detecting oil spills could involve the integration of a satellite into a total surveillance scheme, if these drawbacks were corrected.

SECTION 1.1.2. SATELLITE DATA

Kirby, M.E.

An Analysis of Digital LANDSAT Techniques for the Detection and Mapping of the Scott Inlet Oil Seep

Report, Intera Environmental Consultants Ltd., to the Canada Centre for Remote Sensing as part of the Artic Marine Oilspill Program xxx 1979, 28 pages

CCRS No. 1019780

The study is a part of the Arctic Marine Oilspill Program (AMOP), and, in co-operation with the Canada Centre for Remote Sensing, the utility of digital image processing techniques has been investigated for the detection and mapping of oil residues in Arctic waters using LANDSAT data. The report includes discussions concerning the background observations of the Scott Inlet oil seep and description of the systems used for the digital analysis. In addition, selected data sets, preprocessing functions, analysis methods, and results obtained from the study are also discussed. Finally, a set of conclusions and recommendations was compiled, based on the research that has been conducted.

SECTION 1.1.3. STUDIES AND INVESTIGATION

Fingas, M.F. et al

Preliminary Results of Remote Sensing Overflights During the Kurdistan Operation

Scientific Studies During the Kurdistan Tanker Incident, Workshop, Proc., Dartmouth, Nova Scotia B2Y 4A2
October 1980, 16 pages

CCRS No. 2004472

On March 15, 1979, the tanker Kurdistan, carrying ca. 30,000 tons of Bunker C fuel oil, was en route from Cape Breton Island to Sept Iles, Quebec, when she encountered heavy pack ice. Sometime during March 15 the vessel developed two cracks in her hull, and during the night of March 15, she broke in two. As a result of the break up, about 7,500 tons of Bunker C oil were spilled into the ice-infested waters of Cabot Strait.

The spill represents Canada's first major oil-in-ice spill, and a number of scientific studies were carried out, both at sea and on shorelines. This publication represents the proceedings of a workshop convened at the Bedford Institute of Oceanography on June 26 and 27, 1979, to discuss preliminary observations and conclusions obtained in these studies.

SECTION 1.1.3. STUDIES AND INVESTIGATIONS

General Electric Co., Space Division

Assessment of the Use of Space Technology in the Monitoring of Oil Spills and Ocean Pollution

Executive Summary, Prepared for National Aeronautics and Space Administration, Langley Research Centre

General Electric Co., Space Division, Valley Forge Space Centre, P.O. Box 8555, Philadelphia, PA 19101
December 1979

CCRS No. 1023088

The study was conducted by the General Electric Company, Space Division and a portion of the assessment was performed by the NASA investigation concerning the potential of space technology in the monitoring of oceanic pollution. The aspects of oceanic pollution treated in the study were: oil pollution due to accidental or deliberate activities of ocean vessels, or natural oil seeps originating from the ocean floor; and accidental or deliberate chemical pollution from industrial or municipal waste disposal.

The primary goal of this study was to determine the potential of remote sensing from satellites in the detection monitoring of oil spills and ocean pollution due to waste disposal. In addition, the study examined the potential impact of other space-aided technologies such as communications and data handling.

SECTION 1.1.3. STUDIES AND INVESTIGATIONS

Gill, R.J. et al

A Feasibility Study of Surface Techniques for the Detection of Oil Under Ice

Spill Technology Newsletter, Vol.4, No.2, March-April 1979, pp.57-68

Canadian Dept. of Fisheries and Environmental Protection Services, Ottawa, Ontario K1A 1C8

NORDCO Ltd., P.O. Box 8833, St. John's, Newfoundland A1B 3T2
April 1979

CCRS No. 1019588

The purpose of this particular work has been to investigate the feasibility of various techniques to provide such detection capabilities. The sensing techniques that were initially considered for possible use are the following: radio frequency and radar, acoustic, optical and spectroscopic, nuclear, and gas sniffer.

From preliminary consideration of these phenomena, it was determined that several showed some possibilities. These were then evaluated in detail.

SECTION 1.1.3. STUDIES AND INVESTIGATIONS

McNeil, W.R./Lapp, P.A.

An Evaluation of Optical Techniques for Remote Sensing of Oil Spills in the Beaufort Sea

Canada Symp. on Remote Sensing, 3rd, September 22-24, 1975, Edmonton, Alberta

Canadian Aeronautics and Space Inst., Suite 406, 77 Metcalfe St., Ottawa Ontario

W.R. McNeil & Associates Inc., Toronto, Ontario
September 1975, 12 pages

CCRS No. 1008831

The selection of optical techniques for remote sensing of oil spills in the Beaufort Sea involves a consideration of various meteorological and ice climatological conditions encountered in the area. In addition, the application of specific optical phenomena (i.e., Fluorescence, Raman, Reflection), will depend strongly upon actual remote sensing objectives (i.e., spill mapping vs. species identification). Within this framework and in response to present practical needs, three broadly defined electro-optical sensor classes (photometric, intensified photometric and thermal) are evaluated in terms of their effective probability for target registration (i.e., oil or ice) under several realistic oil/ice/water configurations. The recommended optical systems for airborne and satellite application are assessed in terms of presently evolving multi-sensor and multi-mission roles.

SECTION 1.1.3. STUDIES AND INVESTIGATIONS

Neville, R.A. et al

Remote Sensing of Oil Spills

Spill Technology Newsletter, Vol.4, No.2, March/April 1979, pp.111-146

Canada Dept. of Fisheries and Environment

Environmental Protection Service, Ottawa, Ontario K1A 1C8

Intera Environmental Consultant, Ltd., P.O. Box 4791, Station E,
Ottawa, Ontario K1S 5H9
April 1979, 36 pages

CCRS No. 1019590

In this paper a preliminary discussion of the experiments undertaken by the Canada Centre for Remote Sensing and the results obtained within the remote sensing component of AMOP are presented.

The two major projects carried out were the oil seep in Baffin Bay off Scott Inlet in September 1978 and the test spill conducted in November 1978 by the American Petroleum Institute off the New Jersey coast or the "Wallops oil spill".

All methods used and sensors exploiting these methods are described, and the summary of the actual flight operations is presented.

SECTION 1.1.3. STUDIES AND INVESTIGATIONS

Oil and Hazardous Materials Program Series (Final)

Studies and Investigation of the Fate and Effect of the Shell Oil Spill, Platform B, Block 26, South Timbalier Bay (December 1970-November 1971)

Resources Technology Corp., Houston, Texas

Environmental Protection Agency, Washington DC, Division of Oil and Hazardous Materials
January 1972, 119 pages

PB-257 598/3ST

This report represents a formal documentation of selected field study activities for one major spill incident which initially occurred offshore Louisiana on December 1, 1970 and lasted until April 6, 1971. The report is based on data and information obtained through three field surveys undertaken by EPA. The purpose of these field studies was to determine the areal extent of the spilled material, the fate of the spill, and the effect of the material on the biota. There were: the Caminada Bay, Barataria Bay, physical, chemical and biological sampling conducted by EPA Region VI personnel assisted by the State of Louisiana; the offshore physical, chemical and biological sampling conducted by EPA Regional personnel; oceanographic and remote sensing surveys; the joint physical, chemical and biological sampling.

SECTION 1.1.3. STUDIES AND INVESTIGATIONS

O'Neil, R.A.

Remote Sensing Component of the Arctic Marine Oilspill Program (AMOP)

Canada Centre for Remote Sensing, 2464 Sheffield Road, Ottawa, Ontario K1A 0Y7
xxx 1980, 17 pages

CCRS No. 1027374

Experiments within the remote sensing component of AMOP were carried out by the Canada Centre for Remote Sensing (CCRS) and funded jointly with the Environmental Protection Service (EPS) of the Department of the Environment to determine the optimal sensor configuration and to recommend an operational configuration for the detection, identification and tracking of oil spills in ice infested waters. Sites of the experiment were Scott Inlet, Baffin Island, NWT (September 1978) and Dump Site 106, New Jersey (November 1978).

SECTION 1.1.3. STUDIES AND INVESTIGATIONS

O'Neil, R.A./Neville, R.A./Thomson, V.

The Recommended Remote Sensing System for the Detection and Tracking of Oil Spills in Canada

Arctic Marine Oilspill Program, Tech. Sem., Edmonton, Alberta, June 3-4, 1980

Canada Centre for Remote Sensing, Limebank Road, Ottawa, Ontario K1A 0Y7 June 1980, 18 pages

CCRS No. 1023217

As a result of four separate remote sensing experiments carried out to determine the optimal techniques for the tracking and detection of oil in ice infested waters, it is now possible to recommend the system which will be the most effective under the wide variety of conditions experienced in Canada. The sensor complement should consist of a laser fluorosensor, an ultraviolet/infrared line scanner (UV/IRLS), a side looking airborne radar (SLAR), a low light level television (LLLTV) and photographic cameras. These sensors must be supported by a real time data annotation, display and analysis system. Were such a package to be mounted on a suitable aircraft, Canada would have a very effective tool for a wide variety of routine ocean surveillance applications.

SECTION 1.1.3. STUDIES AND INVESTIGATIONS

O'Neil, R.A./Thomson, V./Neville, R.A.

Remote Sensing of Oil During the Kurdistan Spill

Canada Environmental Impact Control Directorate, Ottawa, Ontario K1A OH3

Canada Centre for Remote Sensing, 2464 Sheffield Road, Ottawa, Ontario K1A 0Y7
xxx 1980, 79 pages

CCRS No. 1029241

The Canada Centre for Remote Sensing (CCRS) was asked to respond to the break-up of the tanker Kurdistan, in order to search for and map the oil which was spilled. This report gives a sortie by sortie summary of the flight operations during the mission, along with a discussion of data treatment and image processing. A detailed data log is given, which contains flight line times and positions, sensor data information, and oil sighting times and locations. The areas in which oil was detected are indicated on the maps of the search zone.

The use of remote sensing during similar oil spill incidents is discussed, and recommendations are made which will allow more effective mobilization and use of remotely sensed information. An algorithm is presented which will allow the determination of the time required to search an area which contains an oil spill. Included are calculations of times that would be required by the three CCRS aircraft types to search the KURDISTAN oil spill area.

SECTION 1.1.3. STUDIES AND INVESTIGATIONS

Reimer, E.M.

The Visual Identification of Bunker-C Oil in Dynamic Pack Ice : Scientific Studies During the Kurdistan Tanker Incident, Workshop, Proc., Dartmouth, Nova Scotia, June 26-27, 1979, pp.74-85

Bedford Inst. of Oceanography, Box 1006, Dartmouth, Nova Scotia B2Y 4A2
October 1980, 12 pages

CCRS No. 2004473

On March 15, 1979, the tanker Kurdistan carrying Ca. 30,000 tons of Bunker C fuel oil, was en route from Cape Breton Island to Sept Iles, Quebec, when she encountered heavy pack ice. Sometime during March 15 the vessel developed two cracks in her hull, and during the night of March 15 she broke in two. As a result of the break-up, about 7,500 tons of Bunker C oil were spilled into the ice-infested waters of Cabot Strait.

The spill represents Canada's first major oil-in-ice spill, and a number of scientific studies were carried out, both at sea and on the shorelines. This publication represents the proceedings of a workshop convened at the Bedford Inst. of Oceanography on June 26 and 27, 1979, to discuss preliminary observations and conclusion obtained in these studies.

SECTION 1.1.3. STUDIES AND INVESTIGATIONS

Smith, C.L.

Determination of the Leeway of Oil Slicks

Virginia Inst. of Marine Science Gloucester Point Coast Guard, Washington DC., Office of Research and Development

Coast Guard Research and Development Centre, Groton, Conn. (366570)
August 1974, 47 pages

AD/A-006 822/1ST

The leeway of oil slicks was determined as a function of wind velocity in the range 5-25 knots to enable more precise forecasting of the trajectory of oil spills, and thus aid effective containment and clean up operations. Leeway was calculated by measurement of the separation of oil slicks from a dyed patch of surface water at sea, using time-sequence nadir aerial photography. Five oil types, No.2, 4 and 6 fuel oils, and light and heavy crude oil were found to exhibit similar leeway as a function of wind speed. Oil spill volume had no measurable effect on leeway, and slicks moved in the direction of the wind. The leeway increases with sea state, and obeys a linear relationship with wind velocity in the wind range studies. Oil spill leeway 'U_0' may be calculated for this wind range from the equation $U_0 = 0.0179\ U_{10} + 0.0196$, where '$U_{10}$' is the apparent spread as viewed at 10 meter elevation. Wind drift factors, obtained by summing oil slick leeway and water surface drift velocities, agree well with values calculated from accidental spills and from laboratory scale tests. The mean wind drift factor found from these experiments is $3.64\% \pm 0.51\%$.

SECTION 1.1.3. STUDIES AND INVESTIGATIONS

Zwick, H.H./Neville, R.A./O'Neil, R.A.

A Recommended Sensor Package for the Detection and Tracking of Oil Spills

EARSEL-ESA Symp., Proc., Voss, Norway, May 19-20, 1981, pp.77-88

European Assoc. of Remote Sensing Labs., 9 Ave., Du Colonel Roche, Toulouse 31029, France, ESA SP-167, July 1981

Canada Centre of Remote Sensing, 2464 Sheffield Road, Ottawa, Ontario K1A 0Y7
July 1981, 12 pages

CCRS No. 1030101

The Canada Centre for Remote Sensing has undertaken a programme to develop oil detection sensors and to specify a system capable of detecting and tracking oil under a wide variety of environmental conditions. The success of remote sensing of oil varies with the severity of these conditions. Oil on open water under clear skies is a relatively easy target; oil under ice presents a formidable task. Several remote sensing experiments were carried out to aid in system design development. Much analysis has been completed, and although the need for more research is indicated, it is possible to recommend the most effective system for the wide variety of conditions experienced in Canada. The recommended sensor complement consists of a laser fluorosensor, an ultraviolet/infrared line scanner (UV/IRLS), a side looking airborne radar (SLAR), a low light level television (LLLTV) and photographic cameras. These sensors must be supported by a real time data annotation, display and analysis system.

SECTION 1.1.4. CURRENT STATUS OF REMOTE SENSING FOR OIL POLLUTION CONTROL IN U.S.A.

Manning, Jr., A.P., Rear Admiral, USCG
White, J.R., Lieutenant Commander, USCG
Vollmers, R.R.

Current Status of Remote Sensing for Oil Pollution Control in U.S. Coastal Waters

Int. Symp. on Remote Sensing of Environment, Proc., 14th, Vol.1, April 23-30, 1980, pp.249-268

The Coast Guard has decided to develop an operational Remote Sensing System for installation on its new medium range aircraft, modified Falcon 20 G's (military designation HU-25A). Each of the 41 aircraft will come equipped with complete provisions to carry the AIREYE System. The AIREYE sensing system will have the capability to detect and map oil spills, and to identify illegally discharging vessels. AIREYE will include: (1) Side Looking Airborne Radar (SLAR), (2) Infrared and Ultraviolet Line Scanner (IR/UVLS), (3) Aerial Reconnaissance Camera (ARC), (4) Airborne Data Annotation System (ADAS), (5) Active Gated Television (AGTV), (6) Control Display and Record Console (CDRC).

The results of previous studies made in satellite oil pollution surveillance were summarized, the demonstrated capabilities of existing satellites were presented and the future events in development of an operational system for both airborne and satellite detection of oil spills were further discussed.

SECTION 1.1.4. CURRENT STATUS OF REMOTE SENSING FOR OIL POLLUTION CONTROL IN U.S.A.

White, J./Breslau, L.R.

Remote Sensing for Oil Pollution Control along Coastal Waters of the United States

Int. Symp. on Remote Sensing of Environment, Proc., 12th, Manila, Philippines, April 20-26, 1978, Vol.1, pp.239-255

ERIM, P.O. Box 618, Ann Arbor, MI 48107

U.S. Coast Guard, Headquarters, Office of Research and Development, Washington, D.C. 20591
April 1978, 17 pages

CCRS No. 1017422

The U.S. Coast Guard has augmented its airborne patrols with remote sensing systems in order to effectively perform its marine environment protection mission. An operational airborne surveillance system has been successfully developed and is currently conducting routine surveillance patrols with the system called "Airborne Oil Surveillance System-II" which evolved from predecessor systems called the "Airborne Remote Sensing System" (ARRS) and the "Airborne Oil Surveillance System-I" (AOSS-I). The currently operational AOSS-II system is destined to be superceded by a system currently under development called the "Airborne Remote Instrumentation System" (AIREYE).

The essential requirements of an operational airborne surveillance system as indicated by the objectives of the remote sensing are that it be able to detect the illegal pollution activity, identify a violator if possible, and confirm the discharge event, and provide data that can be used in the event of subsequent legal proceedings, such as pollutant quantity, accurate position, etc., in near real time, under all-weather, day/night conditions.

SECTION 1.1.4. CURRENT STATUS OF REMOTE SENSING FOR OIL POLLUTION CONTROL IN CANADA

Kingham, J.D./ O'Neil, R.A.

The Remote Sensing Requirements for Oil Spills in Canada

Airborne Remote Sensing of Oil Spills in Coastal Waters, Workshop, Proc., Washington D.C., April 18-20, 1979, pp.79-80

U.S. Coast Guard, Office of Research and Development, Washington, D.C. 20591

Can. Dept. of Environment, Ottawa, Ontario K1A 0H3
January 1981, 2 pages

CCRS No. 1028037

This paper describes some of Canada's remote sensing needs in the oil spill area and addresses some of our approaches for solving these requirements. Remote sensing, for our purposes, is considered to encompass a number of techniques and does not only consist of airborne surveillance.

SECTION 1.1.4. CURRENT STATUS OF REMOTE SENSING FOR OIL POLLUTION CONTROL IN CANADA

O'Neil, R.A.

The Application of Presently Available Sensors for Airborne Oil Pollution Surveillance

Requirements for the Control of Vessel Source Pollution, Appendix A, Transport Canada

Canada Centre for Remote Sensing, (DEMR), Ottawa, Ontario K1A 0Y7
April 1976, 51 pages

CCRS No. 1009076

A survey is made of a number of sensors which may be suitable for the airborne surveillance of Canadian territorial waters. Emphasis is made of the application of these sensors to the detection and identification oil spills. The following sensors are considered: a side looking radar, an infrared/ultraviolet line scanner, a forward looking surveillance radar, a low light level television, a profiling microwave radiometer, a camera system, an illumination system for night-time photography, a laser fluorosensor and a forward looking infrared radiometer. While not all of these sensors may be necessary at any one time, it is noted that the data from the individual sensors is usually complementory; thus, one sensor does not make the others redundant. As well as real time displays, a suitable method of data storage, with access to allow annotation, must be provided for the data.

SECTION 1.1.4. CURRENT STATUS OF REMOTE SENSING FOR OIL POLLUTION CONTROL IN CANADA

Thomson, K.P.B./Ross, S.L./Howard-Lock, H.

Remote Sensing of Oil Spills

Environmental Protection Branch, (Envir. Canada), Economic and Technical Review Department EPS-3-EE-74-2

Canada Centre for Inland Waters, (Envir. Canada), Burlington, Ontario L75 4I6
December 1974, 28 pages

CCRS No. 1038963

The Canadian Federal Government, working together with agencies of other governments, is conducting a number of programs related to detection and clean-up of oil spills in the environment.

In both the environmental assessment and clean-up aspects remote sensing technology provides a vital input. This report discusses the state of the art in the remote detection of oil spills specifically in terms of Canadian experience and needs. Three basic types of sensor "packages" are discussed. These are: passive imagery techniques operating in the visible spectrum, microwave systems and active or specialized techniques. Each of these three categories has certain advantages and disadvantages. For example, single aerial photography or airborne multispectral scanner systems, operating in the visible range of the spectrum, are limited by meteorological conditions and to daytime operation.

Requirements of quasi-operational airborne systems include all weather capability which can be accommodated by microwave systems. Microwave systems can also be used for night-time surveillance and, under certain conditions, for estimating the thickness of oil. The third category

covers instrumentation such as active laser line scanner systems (useful for night operations) and laser fluorosensors which may provide means of identifying oil type as well as distinguishing between oil and chemical effluents.

SECTION 1.1.4. CURRENT STATUS OF REMOTE SENSING FOR OIL POLLUTION CONTROL IN FRANCE

Burkhalter, Roland Meyer, Claude Massin, Jean-Marie

Current Status of Remote Sensing for Oil Pollution Control in French Coastal Waters

Int. Symp. on Remote Sensing of Environment, Proc., 14th, Vol.1, April 23-30, 1980, San Jose, Costa Rica

Environmental Research Inst. of Michigan, Ann Arbor, Michigan

The experimental studies carried out by the "Centre National pour l'Exploitation des Oceans" (CNEXO) and the "Institut Francais du Petrole" (IFP), as set up by the Ministry of the Environment, resulted in purchase of a remote sensing system for airborne surveillance. These operations have been assigned to the External Department of the Merchant Navy. The system is composed of two sub-systems: (1) an airborne detection system including an infrared line scanner (with video display and recording devices added), cameras and additional equipment used on board a light twin-engine aircraft (CESSNA FTB 337); (2) an on-ground system for data reception and real time viewing.

ADDENDUM FOR SECTION I

PETROLEUM INDUSTRIES

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Fluoroscence Spectroscopy and Raman Spectroscopy

Sylva, P. da/Menard, P./Roy, P.
Till, S.M./Nevile, R.A./O'Neil, R.A.

Real Time Data Correlator for Airborne Laser Fluorosensor

International Society for Photogrammetry and Remote Sensing Proceedings, Commission II, Symp. on Advances in Instrumentation for Processing and Analysis of Photogrammetric and Remotely Sensed Data, Ottawa, Canada, August-September 1982

International Archives of Photogrammetry, Vol.24-II, ISSN 0252-8231
September 1982, 8 pages

CCRS No. 1037587

An Airborne Fluorosensor Data Correlator has been designed and developed for the Canada Centre for Remote Sensing, to identify in real-time fluorescent targets such as oil, by recognition of the laser induced fluorescence signature. The correlator, which is interfaced to the CCRS laser fluorosensor, compares the fluorescence spectrum collected in real-time with stored reference spectra. Normalized correlation operations are performed, with the resulting correlation coefficients for up to six reference spectra being displayed on a colour monitor. Input data from the fluorosensor can also be collected and used as one of the reference spectra for subsequent correlations. An alarm is activated when any of the correlation values exceeds a threshold limit. In addition, the correlator unit displays the output from a single fluorosensor channel, corresponding to the water Raman signal, and the average total fluorescence signal. Features of the instrument include switch selectable data averaging, adjustable threshold limits, serial output, a colour graphics display with time annotation, freeze option and automatic scaling, and a full range of diagnostic features.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Microwave Radiometry

Singh, R.P.

Microwave Remote Sensing of Oil Slicks Over the Ocean Surface

Institute of Earth and Planetary Physics, Dept. of Physics, University of Alberta, Edmonton, Alberta, T6G 2J1
21 pages

CCRS No. 1038334

Offshore oil exploration and indiscriminate dumping of various wastes create serious problems to active and passive remote sensing of ocean surface properties namely, surface temperature and turbulence. In this paper we have considered the effect of oil slick thickness over the ocean surface and have studied the response of microwaves in both the polarizations. With the help of a model of varying slick thickness backed by ocean surface, we have accounted for multiple reflection during the oil slicks. The reflection coefficients for both polarizations have been computed as functions of slick thickness and operating frequencies. It is shown that the brightness temperature increases with increasing thickness of oil slicks. The nature of the variation of brightness temperature is found to be oscillating. The frequency variation of brightness temperature increases steadily with increasing slick thickness and becomes maximum towards the lower operating frequencies. Such model calculations may be very helpful in interpretation of active and passive microwave remote sensing data of the ocean surface.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Radar System

Johnson, J.W./Croswell, W.F.

Characteristics of 13.9 GHz Radar Scattering from Oil Films on the Sea Surface

Radio Science, Volume 17, No.3, pages 611-617, May-June 1982

NASA Langley Research Centre, Hampton, Virginia 23665
November 1981, 8 pages

CCRS No. 1038132

An aircraft remote sensing project to study the response of a number of active and passive microwave and optical remote sensors to an oil-covered sea surface was conducted by NASA Langley Research Centre in 1979. Included was a 13.9 GHz Doppler scatterometer, with a fan beam antenna and coherent detection, to measure radar backscatter as a function of incidence angle. The purpose of this paper is to present a comparison between the radar scattering signature of the clear surface and the signatures of the surface while covered with a variety of crude oil films. The film were deposited on the surface from ships. Both in situ data and infrared aerial photography provided surface truth. Scattering changes were observed over a range of incidence angles from nadir to approximately 60°. Results show up to 14-db reduction in backscattered power between the clear surface and the films for horizontal polarization at an incidence angle of approximately 30°. In all cases the greatest reduction in backscatter due to the oil was observed at approximately 30°, which suggest an optimum incidence angle for oil detection and mapping at 13.9 GH_z. Maximum reduction in backscatter also appear to occur where the oil is the thickest.

SECTION 1.1.1. AIRBORNE REMOTE SENSING

Radar System

Soofi, K./Moore, R.K.

Required Resolution for Radar Oil Spill Detection : A Preliminary Study

Remote Sensing Laboratory Centre for Research, Inc., The University of Kansas, Lawrence, Kansas 66044

RSL Technical Report, RSL TR 389-2, May 1980, NASA Langley Research Centre, Hampton, Virginia 23665
May 1980, 34 pages

CCRS No. 1035477-1035480

Resolution requirements for discrimination of oil spills with imaging radars have been studied. A synthetic-aperture radar image containing two spills was degraded on a digital processor to a series of equivalent larger pixels than on the original image. The oil spills could be located with a system having equivalent photographic pixels having almost the same area as the spills themselves. Reasonable representation of the spill was obtained when the equivalent photographic pixel area was half the area of the oil spill. Proper definition of the shape of the spill required some what finer resolution.

Both square and rectangular pixels were used in the analysis, although the range of aspect ratios studied for the rectangular pixels was not as complete as desirable. Results with aspect ratios up to 50:1 were quite satisfactory provided the total area of the pixel was suitable. This makes tradeoffs in radar system design between the high power required for good range resolution and the long aperture required for good along-track resolution.

SECTION 1.1.3. STUDIES AND INVESTIGATION

Burlamacchi, P./Cecchi, G./Mazzinghi, P./Pantani, L.

Performance Evaluation of UV Sources for LIDAR Fluorosensing of Oil Films

Applied Optics, Vol.22, page 48, January 1, 1983
Copyright 1983 by the Opitcal Soceity of America

CNR Istituto salla Ricerca delle Onde Elettromagnetiche, 50127 Firenze, Italy

CNR Istituto di Elettronica Quantistica, 50127 Firenze, Italy
January 1983, 6 pages

CCRS No. 1038078

A laboratory experiment is discussed which simulates LIDAR fluorosensing of oil films on the sea surface at UV wavelengths. Three different mixtures of lasing gases, KrF, XeCl and N2 were used while a fourth wavelength was given by a dye laser. It turns that films having a thickness as low as 0.01μm can be detected; the limiting factor resides mainly in the background fluorescence of water. Best results have been obtained with the XeCl excimer laser.

SECTION 1.1.3. STUDIES AND INVESTIGATION

Sorensen, B.M./Sturm, B./Tassan, S.

Some Results from Experiments on Remote Sensing of Water Quality and Oil Pollution in the Mediterranean Sea

Proceedings of the Int. Symp. on Remote Sensing, "Remote Sensing of Arid and Semi-Arid Lands" Vol.1, January 19-25, 1982, Cairo, Egypt

Commission of the European Communities Joint Research Centre, I-21020 Ispra (Va.) Italy
January 1982, 9 pages

CCRS No. 1036881

The Joint Research Centre (JRC) of the commission of the European Communities (CEC) has worked for some years on problems related to satellite and aircraft sea water quality monitoring.

As a member of the NIMBUS-7 Experiment Team (NET) on the Coastal Zone Colour Scanner (CZCS), JRC has contributed to the development of algorithms for atmospheric correction of CZCS data to quantify phytophlankton (chlorophyll) and suspended inorganic matter in the sea.

JRC is carrying out a series of remote sensing experiments in the Mediterranean Sea aiming at seston quantification and oil pollution monitoring. Some results from such experiments are presented.

It is illustrated that CZCS data can be used to discriminate quantities of chlorophyll in the range of 0-10 mg/m^3 with reasonable precision, but relatively poor accuracy.

The first results are also presented from an oil spill experiment made to determine the detection limits of several types of oil on the sea surface, using synthetic and real aperture radars, and an ultraviolet/infrared scanner.

1.2.0. REMOTE SENSING IN MINING INDUSTRIES

1.2.1. Airborne Remote Sensing
- Multiband and Standard Photography

1.2.2. Satellite Data (ERTS, LANDSAT and EREP - Sky Lab)

SECTION 1.2.1. AIRBORNE REMOTE SENSING

Multiband and Standard Photography

Bush, R.A./Backer, R.R./Atkins, L.A.

Physical Property Data on Coal Waste Embankment Materials

Bureau of Mines, Spokane, Washington, Spokane Mining Research Centre (390057)
November 1974, 149 pages

PB-240 022/4ST

Engineering design criteria for coal tailings embankments have been totally lacking, resulting in hazardous impoundment structures in coal mining areas. A necessary first step to develop design criteria is the determination of basic representative physical property data on the materials that constitute typical tailings embankments. An extensive field and laboratory program was undertaken by the U.S. Bureau of Mines, Spokane Mining Research Centre. Much physical property data was generated. Additional photographic analysis and large-scale triaxial compression testing was performed by other agencies. The data presented here should be extremely valuable in establishing design parameters for coal tailings impoundments.

SECTION 1.2.1. AIRBORNE REMOTE SENSING

Multispectral and Standard Photography

Hughes, T.R./Dillion, A.C./White, J.R., Jr./Drummond, S.E., Jr. and Hooks, W.G.

Assessment of Practicality of Remote Sensing Techniques for Study of the Effects of Strip Mining in Alabama

Final Report, July 1, 1973 - June 30, 1975

Alabama University, P.O. Box 2846, University, Alabama 35486

Some of the more important aspects of the research project entitled "Assessment of Practicality of Remote Sensing Techniques for a Study of the Effect of Strip Mining in Alabama" are outlined below:

1. The introductory section describes the structural setting and the stratigraphy of the Pottaville Group in the Warrior Coal Basin.

   Two areas in the Warrior Coal Basin were selected for study. The Cordova area is a test site of approximately 23 square kilometers near the town of Cordova, Alabama. Contour stripping has occurred continuously since 1967 and intermittently prior to that time. Two coal beds in the Mary Lee Group are the principal pay zones. The Searles Area is a study site which covers about 18 square kilometers west of the town of Searles, Tuscaloosa County, Alabama. This area has been mined almost continuously since 1944 by stripping. Coal is produced from four coal beds in the Brookwood Coal Group. During the second year of study, all research was conducted in the Searles Area.

2. Areal Extent of Strip Mining

The only photographs provided for this study were taken by NASA-MSFC in December, 1973. Measurements to determine the extent of mining were taken from these photographs.

Cordova Area - This study area covers 3266 hectares of which 516.76 have been affected by strip mining (15.8% of the total). Sub-areas are identified and categorized by age of mining.

Searles Area - The total area covered by NASA photography is 5036.4 hectares of which 953.03 hectares have been strip mined (18.9% of the total). Sub-areas are identified and categorized by age of mining.

SECTION 1.2.2. SATELLITE DATA - ERTS, LANDSAT AND EREP

Amato, R.V./Russell, O.R./Martin, K.R./Weir, C.E.

Application of EREP, LANDSAT and Aircraft Image Data to Environmental Problems Related to Coal Mining

NSAS Earth Resources Survey Symp., Proc., 18th, Vol.1-A
June 1975, Houston, Texas

National Aeronautics and Space Administration, Lyndon B. Johnson Space Centre
June 1975, 18 pages

CCRS No. 1007136

The synoptic and sequential analysis of aerial remote sensing records provides valuable environmental and dynamic change data in areas of both surface and underground coal mining. Depending upon the accuracy required, these data are available through both low and high level aircraft surveys as well as LANDSAT and EREP (SKYLAB) imagery. Remote sensors can provide timely and accurate information on surface mining status and reclamation progress, coal mine refuse piles and slurry ponds, acid water and siltation problems, and various aspects of environmental impact. With two concurrently-orbiting earth resources satellites (LANDSAT 1 and 2) providing repetitive coverage every nine days, mining-environmental data can be supplied to state and federal agencies in a timely manner. This is particularly important because of the accelerated development of coal resources to meet unprecedented energy demands.

Remote sensing techniques were used to study coal mining sites within the Eastern Interior Coal Basin (Juliana, Illinois, and Western Kentucky), the Appalachian Coal Basin (Ohio, West Virginia and Pennsylvania) and the anthracite coal basins of north-eastern Pennsylvania. Remote sensor data evaluated during these studies were acquired by LANDSAT, SKYLAB and both high and low altitude aircraft. Airborne sensors included multispectral

scanners, multiband cameras and standard mapping cameras loaded with panchromatic, colour and colour infrared films.

The research that has been conducted in these areas is a useful prerequisite to the development of an operational monitoring system that can be periodically employed to supply state and federal regulatory agencies with supportive data. Further research, however, must be undertaken to systematically examine those mining processes and features that can be monitored cost-effectively using remote sensors, and for determining the appropriate combination for an operational system. The preliminary studies described in this paper supply information useful for directing the scope of this necessary follow-on research.

SECTION 1.2.2. SATELLITE DATA - ERTS, LANDSAT AND EREP

Ambionics, Inc., Washington, D.C.

Remote Sensing of Coal Mine Pollution in the Upper Potomac River Basin
Ambionics, Inc.

Ambionics, Inc., 400 Woodward Building, Washington, D.C. 20005
1974, 70 pages

N74-34817/8ST

Remote sensing study from the Earth Resources Technology Satellite (ERTS) and from aircraft were compared with data obtained by traditional field methods of surface sampling, to monitor water pollution caused by mining activities (both active and abandoned) in the upper Potomac River, was conducted in August 1973 by Ambionics, Inc. It was found that usage of ERTS imagery in monitoring strip mining activities was much more rapid and accurate than methods currently employed. Aircraft photography represents the "fine tuning" in the search for mine drainage pollution and should be undertaken at least four times per year (once each season). The time of flight should be established to coincide with satellite passes, so as possibly to relate aircraft coverage with field samples in case high cloud cover preclude analysis for ERTS imagery.

Polluted water, treated and untreated, was showing up around the North Banch Mine at Bayard, West Virginia in varying shades of green on the colour infrared aerial photography. The green water appearance on aircraft imagery where water is known to contain mine pollution, by extrapolation from the work of Carl H. Standberg, is an indication of an extremely high biological oxygen demand (BOD) which results from the utilization of most of the water's available oxygen by the mine pollution to form sulfuric acid. Those few organisms that can survive under this low pH and low available oxygen are certain algae and specific forms of bacteria, which are associated with the alga Ulothrix spp. This shows that the green near-infrared response is an indicator of mine acid pollution.

SECTION 1.2.2. SATELLITE DATA - ERTS, LANDSAT AND EREP

Gregory Geoscience Limited

An Assessment of the Potential Use of Remote Sensing Technology for Monitoring Mine Waste Dumps, Vol.I : Development Techniques for

Canada Centre for Mineral and Energy Technology, Contract #OST4-0150

Gregory Geoscience Limited, 1750 Courtwood Crescent, Ottawa, Ontario K2C 2B5
April 1975, 68 pages

CCRS No. 1008997

For some years, remote sensing from aircraft and satellites has had a recognized potential for assisting in mine wastes monitoring. In particular, LANDSAT (formerly ERTS, NSAS's Earth Resources Technology Satellite) provides relatively inexpensive, repetitive data that could facilitate such an inventory as well as subsequent monitoring. Accordingly, Gregory Geoscience Limited proposed and was awarded a contract in August 1974, to assess the potential of remote sensing for monitoring mine wastes.

A literature review revealed that current techniques for assessing mine waste using LANDSAT data could identify a few general classes, such as water, vegetated terrain and stripped land, and could measure areas in excess of 2 to 4 hectares (5 to 10 acres) with acceptable accuracy. All techniques appeared to require further development for operational use. In particular, additional research was needed to define spectral classes of mine wastes.

Test sites were selected in three areas: Elliot Lake and Sudbury in Ontario, and Bristol, Quebec. LANDSAT data were acquired for these areas. Airborne sensing and field studies were carried out at selected test sites. Visual and digital classifications of LANDSAT data were assessed in the context of measured parameters at test sites in order to develop a technique for mapping mine wastes.

SECTION 1.2.2. SATELLITE DATA - ERTS, LANDSAT AND EREP

Gregory Geoscience Limited

An Assessment of the Potential Use of Remote Sensing Technology for Monitoring Mine Waste Dumps, Vol.II : Experimental Inventory of Mine Wastes

Canada Centre for Mineral and Energy Technology, Contract No. OST4-0150

Gregory Geoscience Limited, 1750 Courtwood Crescent, Ottawa, Ontario K2C 2B5
April 22, 1975, 63 pages

CCRS No. 1008998

Abstract is the same as for Vol.I (page 2-6)

SECTION 1.2.2. SATELLITE DATA - ERTS, LANDSAT AND EREP

Moore, H.D./Adams, J.H./Gregory, A.F.

Mapping Mine Wastes with LANDSAT Images

Presented at the Canadian Symp. on Remote Sensing, Quebec City, May 1977

Gregory Geoscience Limited, Ottawa, Ontario
May 1977, pages 294-304

Techniques for visual classification and mapping of mine wastes from LANDSAT and supplementary data were developed and tested by the authors in 1974-75. These techniques were subsequently used to complete an inventory of mine wastes across Canada. The work was completed under contract to the Canada Centre for Mineral and Energy Technology.

Surficial materials at mine sites were sub-divided into four classes of mine waste (overburden, tailings, waste rock and slag), two classes of water, two classes of vegetational covers and two classes of mining facilities. 718 mine sites were studied and classifiable wastes were detected at 399 sites. Inventory sheets were prepared for all such areas in excess of 10 hectares.

The total area of mine wastes is the inventory in 47,233 hectares, which is 0.004% of the area of Canada. Of that total, about 46.8% is overburden, 37.3% tailings, 15.3% waste rock and 0.6% slag. About 14.8% of those wastes have vegetational cover.

Total cost of development and inventory was about $91 per mine site in the inventory. The inventory alone cost about $60 per mine site and required about 266 man-days of work.

It was concluded that visual interpretation was the most practical technique for mapping mine wastes at the present time. Such a technique was developed and tested in an experimental inventory. The results showed that, for the given scale and classes of waste, a national inventory of mine wastes could be completed at relatively low cost using the newly developed technique.

1.3.0. REMOTE SENSING IN FOREST INDUSTRIES

1.3.1. Airborne Monitoring
- Fluorescence Spectroscopy
- Multispectral Photography

1.3.2. Satellite Data - ERTS-1

SECTION 1.3.1. AIRBORNE MONITORING

Fluorescence Spectroscopy

Bristow, M.P.F.

Airborne Monitoring of Surface Water Pollutants by Fluorescence Spectroscopy

Remote Sensing of Environment RSEE-A, 1978-04 007 002 105-127

EPA, Environment Monitoring and Support Lab., Las Vegas, Nevada
April 1978, 22 pages

CCRS No.

An airborne laser fluorosensor has been used to record fluorescence profiles of a controlled oil spill and of the river effluent from a pulp and paper mill. A pulsed ultra-violet laser is used as the excitation source in conjunction with a telescope receiver and photomultiplier/detector. The complete system, including power supplies and monitoring and recording equipment, was installed and flown on a Canadian Forces DC-3 aircraft. The fluorescence profiles exhibited excellent signal-to-noise ratios and ground resolution, thereby providing for good discrimination between targets of different fluorescence quantum efficiency. By making a number of passes over a particular target area, it has been shown how the measured fluorescence profiles demonstrate the manner in which the target changes both in space and time. Information gained from these remote sensing measurements has provided data for use in the design of an advanced laser fluorosensor capable of recording fluorescence spectra and decay/time data in addition to fluorescence profiles similar to those presented here.

SECTION 1.3.1. AIRBORNE MONITORING

Multispectral Photography

Burgess, F.J./James, W.P.

Aerial Photographic Testing of Pulp Mill Effluent in Marine Waters

U.S. Federal Water Quality Assoc., 1521 Gingerwood Ct., Vienna, VA 2180

Oregon State University, Department of Civil Engineering, Corvallis, OR 97331
August 1970, 152 pages

CCRS No. 1016346

Aerial photography of effluent plums from kraft pulp mill ocean outfalls was shown to be an effective tool for the study of waste disposal sites. This technique is not limited by sea conditions and permits monitoring and evaluation of outfall slites throughout the year. Photography taken at one instant provides comprehensive information throughout the waste field. Manpower requirements and costs for this method are considerably less than for conventional boat sampling surveys. Field studies were conducted on the waste plumes from kraft pulp mill ocean outfalls at Newport and Gardiner, Oregon and Samoa, California. Waste concentration were measured by conventional boat sampling techniques while aerial photography was taken of the outfall area at altitudes ranging from 3,000 to 11,000 ft. Computerized procedures were used to compute water currents, waste concentrations, toxicity zones and diffusion coefficients from the photography. The maximum concentration determined over the outfall for each field study was generally less than that shown to have a detrimental effect on young salmon for a 14-day exposure. Surface water currents were found to determine the resulting plume pattern. During periods of low current velocities in receiving waters, the hydraulic head created by the effluent discharge was a significant factor in the resulting plume shape. The steady state form of the Frickian diffusion equation and undirectional transport velocity was not applicable to the majority of these observations.

SECTION 1.3.1. AIRBORNE MONITORING

Multispectral Photography

James, W.D./Burgess, F.J.

Pulp Mill Outfall Analysis by Remote Sensing Technique

Oregon State University, Corvallis, Oregon

Tappi, Vol.54, No.3
March 1971, 4 pages

CCRS No.

Report on research work which aimed to develop areial photographic methodology for the quantitative evaluation of dispersion of pulp mill wastes from existing or potential ocean outfalls. Aerial photography of the waste field was taken with a multispectral camera system while boat sampling was conducted to provide "ground truth" data. Data have been compiled and analyzed by a computerized procedure to relate water quality to photographic imagery. Discrepancies between concentrations determined by boat sampling and concentrations determined photographically appear to be due to variable dispersal and transport of the wastes in this dynamic environment.

SECTION 1.3.1. AIRBORNE MONITORING

Multispectral Photography

Scherz, J.P./Graff, D.R./Boyle, W.C.

Photographic Characteristics of Water Pollution

Photogrammetric Engineering, Vol.35, No.1, January 1969

University of Wisconsin, 500 Lincoln Drive, Madison, WI 53706
January 1964, 7 pages

CCRS No. 1011528

Special aerial photography can be used to advantage in detecting and photographing water pollution. For photographing waste from a paper mill discharging into the Wisconsin River the Kodak Film Type 8443 with a #4 or #12 filter proved best with a camera setting of 1/500 sec. at F.4.5. The wavelengths photographed in this case were from approximately 0.5 to 0.9 microns. Heat effects could not be photographed directly. However, it was possible to detect some secondary effects caused by the heated water churning as it entered the cooler bodies. Some film-filter combinations showed this foam better than the human eye could see it while other film-filter combinations did not show it at all. Some film-filter combinations showed only the surface of the water while others penetrated very well and showed deep-lying weed beds.

SECTION 1.3.1. AIRBORNE MONITORING

Multispectral Photography

Tomlins, G.F./Manore, M.

The Potential of Remote Sensing for Monitoring Pulp Mill Effluents
Presented at Seminar on Pulp Mill Effluents, Vancouver, B.C., March 1982

B.C. Research, 3650 Wesbrook Mall, Vancouver, B.C., V6S 2L2

This paper reviews the remote sensing options that are available for monitoring effluents from pulp and paper mills. A brief description of a novel remote-controlled aerial sensor platform under development by B.C. Research is given and the possible applications of this platform to pulp mill effluent monitoring are discussed.

SECTION 1.3.2. SATELLITE DATA - ERTS-1

Lind, A.O./Hensen, E.B.

Pollution Monitoring in Lake Champlain Using ERTS-1 Imagery

NASA Contract NAS 5-21753

University of Vermont, Remote Sensing Lab., Burlington, VT 05401
June 1972, 8 pages

CCRS No. 2002643

ERTS imagery has provided data relating to a number of environmental and limnological concerns such as water quality, lake flooding and lake ice formation. Pollution plume data provided by ERTS was recently used in a Supreme Court case involving the States of Vermont and New York and a paper company. Flooding of lowland tracts has been a major concern due to a repetitive pattern of high lake levels over the past three years, and ERTS imagery is being used to construct the first series of flood maps of the affected areas. Lake ice development and turbidity patterns have also been studied from ERTS, since these have significance for shore erosion studies.

1.4.0. REMOTE SENSING OF SEWAGE SLUDGE & MUNICIPAL WASTES

1.4.1. Airborne Monitoring
- Infrared Imagery
- Multiband Photography

1.4.2. Satellite Data - LANDSAT

1.4.3. Study and Investigation

SECTION 1.4,1. AIRBORNE MONITORING

Infrared Imagery

National Field Investigation Centre, Denver, Colorado

Remote Sensing Report, Baltimore Harbour and Wicomico River Basin, Maryland

National Field Investigation Centre, Denver, Colorado
PB-255 592
March 1974, 205 pages

CRS No. 2003123

An aerial remote sensing study of Baltimore Harbour and the Wicomico River Basin was conducted on May 9, 1973. This investigation was undertaken at the request of the Department of Natural Resources, State of Maryland. The purpose of the Baltimore Harbour study was to document the presence of discharges of wastewater to the Harbour from municipal and industrial sources, storm drains, and other unidentified sources. Photographic and thermal infrared data were recorded during the day and thermal infrared data were recorded at night using sensors mounted in high performance reconnaissance aircraft. No ground truth data was collected. All observed discharges were compared with known municipal and industrial wastewater discharge permits. In addition, the relative magnitude, colour, dispersion behaviour and, in some cases, relative levels of concentration of the detected discharges and resulting plumes were documented.

SECTION 1.4.1. AIRBORNE MONITORING

Infrared Imagery

Petrilli, F.L./De Penzi, G.P./Morelli, R.P./De Flora, S.

Survey of the Pollution in a Coastal Area of the Tyrrhenian Sea

Aerial Photography, Physico-Chemical and Microbiological Investigations and Mutagenic Monitoring

Water Research, Vol.13, p.895-904
xxx 1979, 10 pages

Investigations were carried out in a coastal area of the Tyrrhenian Sea, which receives wastes from a chemical manufacturing industry. Industrial wastes are combined with domestic sewage prior to discharge into the sea. Warm and alkaline wastewaters carry large amounts of whitish suspended solids, mainly composed of calcium carbonate, calcium sulphate, and magnesium hydroxide, which are responsible for an evident visual pollution of the sandy shore and of the facing sea-water body. Alterations of physical parameters (temperature and pH values) were found to affect the investigated coastal area only to a limited extent. Conversely, aerial photographic investigations afforded a more complete picture of pollution spreading. Infrared and chiefly water-penetration images provided information on the underwater environment, and the resulting findings could be correlated with the particle size analysis of sediment samples. Faecal streptoccocci represented a considerable proportion of total heterotrophic bacteria in waste and sea-water, whereas concentration of total and faecal coliforms was relatively low. These figures suggested a possible selective inactivation of bacteria in industrial waters, which was supported by the findings of survival tests with three bacterial species (E. Coli, Strep. faecalis and S. typhi). Survival of a virus (type 1 Phliovirus) and a virus antigen (hepatitis B surface antigen or HBSAG) was also investigated under various conditions.

SECTION 1.4.1. AIRBORNE MONITORING

Multispectral Photography

Schmidt, D.

Use of Aircraft Remote Sensing on Problems in Marine Chemistry and Pollution Research and Monitoring

Remote Sensing for Observation and Inventory of Earth Resources and the Endangered Environment, Int. Symp., Proc., Freiburg, W. Germany, July 2-8, 1978, Vol.II, pp.1203-1211

Dr. G. Hildebrandt, University Freiburg, ABT, Luftbildmessungund Interpretation, Freiburg, W. Germany
July 1978, 9 pages

CCRS No. 1026666

An experimental "chemical marine pollution" has been performed in the German Bight to investigate possibilities for determining chemical parameters from the sea surface. As an example, the continued dumping of waste solutions from titanium dioxide production northwest of Helgoland Island was taken. Here, distinct colour variations in sea water can be observed. The relevant chemical processes have been monitored by Deutsches Hydrographisches Institute for a number of years by means of research vessels. The flight campaign on August 25, 1976 is described, simultaneous measurements at sea as well as pictures and data from remote sensing are presented, and examples of digital image processing are given. Experience from the experiment can be taken as a valuable input for future modified flight campaigns as well as a basis for later satellite use. Briefly, a LANDSAT 1 picture is discussed, where traces are discernable in the investigation area that may be related to the same dumping activities.

SECTION 1.4.2. SATELLITE DATA - LANDSAT

Johnson, R.W./Ohlhorst, C.W.

Application of Remote Sensing to Monitoring and Studying Dispersion in Ocean Dumping

Ocean Dumping of Industrial Wastes, Marine Science, Vol.12, pp.175-191, November 1980

The draft and dispersion of sixteen acid waste plumes 64 km. off the Delaware coast were investigated using LANDSAT imagery, current drogues and ship data. The waste plumes imaged by LANDSAT were found to be drifting at average rates from 0.59 km. hr^{-1} to 3.39 hr^{-1} into the southwest quadrant. The plumes seemed to remain above the thermocline which was observed to form from June through August at depths ranging from 13 m. to 24 m. During the remainder of the year the ocean at the test site was not stratified, permitting wastes to mix throughout the water column.

The magnitudes of calculated plume drift velocities were compatible with the drift velocities of current drogues released over a 12-month period at the surface, at mid-depth and near the bottom. However, during the stratified warm months, more drogues tended to move in the north-northeast direction, while during the non-stratified winter months a southwest direction was preferred.

Rapid waste movement toward shore occurs primarily during storms, particularly northeasters. During such storms, however, the plumes are rapidly dispersed and diluted. The plume width was observed to increase at a rate of about 1.5 cm. sec^{-1} during calm sea conditions, yet attain spread rates in excess of 4 cm. sec^{-1} on windy days. These results indicate that by the time a waste plume would reach shore, dilution would be at least one million to one.

SECTION 1.4.3. STUDIES AND INVESTIGATIONS

Escudero, C.A.

Colour and Colour Infrared Photography for Determination of Polluted Flows by Use of Patterns Taken from Sewage Treatment Plant Pnds

Remote Sensing of Earth Resources, Vol.3, Conf. on Earth Resources Observations

Space Inst., (University of Tennessee), Tullahoma, TN 37388

University of Chile, R/S and Earth Resources Geodetics Department, Casilla, 2777, Santiago, Chile
March 1974

CCRS No. 1005492

The aim of this work is to find, as a first stage, the best combination of film and filter to show differences of water quality, especially related with the presence of dissolved oxygen. For this qualitative work I counted with 35 mm photographic cameras, films (Ektachrome-X, Ektachrome Infrared and Agfachrome) and filters (Kodak Wratten 14 and 25, HOYA UV, SPIRALITE G). All possible combinations were used to get pictures of a colour panel in a water sample. Measures were taken of dissolved oxygen, pH, turbidity and temperature from each sample and it was photographed at the same time with different films and filters.

Best results determinating dissolved oxygen differences are found with Agfachrome, without filter or with UV filter.

It was found too, that it is difficult to compare pictures taken during sunshine and on a cloudy day. Better results are obtained during early morning or late afternoon.

In a second stage counting with a densitometer will be tried to get some quantitative results.

SECTION 1.4.3. STUDIES AND INVESTIGATIONS

Johnson, R.W.

Remote Sensing and Spectral Analysis of Plumes from Ocean Dumping in the New York Bight Apex

Remote Sensing of Environment, Vol.9, No.3, May 1980, pp.197-209

Elsevier-North Holland Pub., Co., 52 Vanderbilt Ave., New York, N.Y. 10017
xxx 1980, 13 pages

CCRS NO. 1024573

Experiments conducted in the Atlantic Coastal Zone indicate that plumes resulting from ocean dumping of acid wastes and sewage sludge have distinguishable spectral characteristics. Remotely sensed wide-area synoptic coverage provides information on these pollution features that is not readily available from other sources. Photographic and multispectral scanner data remotely sensed from aircraft were interpreted by two methods. First, qualitative analyses in which pollution features are located, mapped, and identified without concurrent sea truth data and, second, quantitative analyses in which concurrently collected sea truth measurement is used to calibrate the remotely sensed data and to determine quantitative distribution of one or more parameters in a plume. For the qualitative analyses, an in-scene calibration technique was developed that "normalizes" environmental effects, thereby potentially providing a means of plume identification that is independent of the specific scene and the multispectral scanner used. Application of this technique to data from several experiments indicates that plumes resulting from acid wastes and sewage sludge have distinctive spectral characteristics over a range of environmental conditions and for two multispectral scanners flown at altitudes of 3.0 and 19.7 km. In addition to qualitative analyses that used in-scene calibration, quantitative analysis techniques were applied to sewage sludge dump plumes. A calibrated regression equation that related remotely sensed radiances to suspended solids concentrations was developed in order to map synoptic suspended solids distributions in plumes.

SECTION 1.4.3. STUDIES AND INVESTIGATIONS

Johnson, R.W./Ohlhorst, C.W.

Application of Remote Sensing to Monitoring and Studying Dispersion in Ocean Dumping

Ocean Dumping of Industrial Wastes, Marine Science, Vol.12, November 1980

Experiments conducted in the coastal waters of the United States indicate that plumes resulting from ocean dumping of sewage sludge and industrial wastes have distinguishable spectral characteristics. Remotely sensed wide-area synoptic coverage provides information on these pollution features that is not readily available from other sources. Results indicate that qualitative analysis techniques may be used for the location, identification, and mapping of plumes resulting from ocean dumping of waste materials. An in-scene background elimination technique was developed that "normalizes" other environmental effects, thereby potentially providing a means of plume identification that is independent of the specific scene and the multispectral scanner used. Application of this technique to data from several experiments demonstrates that plumes resulting from sewage sludge and several industrial wastes have distinctive spectral characteristics over a range of environmental conditions and for two multispectral scanners flown on aircraft at altutides of 3.0 and 19.7 km.

In addition to qualitative analyses that used in-scene background elimination, quantitative analysis techniques were applied to remotely sensed data and suspended solids in sewage sludge plumes and iron concentrations in acidic iron waste plumes. Calibrated regression equations from the multiple regression-analyses were applied to map quantitative distribution of those parameters in remotely sensed scenes. These quantitative value and/or radiance differences also have been used to study the temporal dispersion of plumes and surface water movement in the dump areas.

SECTION 1.4.3. STUDIES AND INVESTIGATIONS

Johnson, R.W./Ohlhorst, C.W./Usry, J.W.

Location, Identification and Mapping of Sewage Sludge and Acid Waste Plumes in the Atlantic Coastal Zones

Joint Conf. on Sensing of Environmental Pollutants, 4th, New Orleans, LA, November 6-11, 1977

Langley Research Centre (NASA), Hampton, VA 23665
November 1977

CCRS NO. 1013631

Results of field experiments conducted in the Atlantic Coastal Zone indicated that pollution features have unique spectral characteristics which may be used to locate, identify and map their distribution, without concurrent sea truth. When an in-scene calibration technique is used sewage sludge and acid waste dump plume identification is independent of environmental effects, the specific remote sensor (photographic or electronic) that collects data in the visible and near infrared portion of the spectrum, and geographical location of the dumping in the Atlantic Coastal Zone. After identification, the extent of the pollution feature can be mapped based on radiance differences between the plume and the surrounding water. In addition, radiance ratio curves (e.g., in-scene calibration) obtained in the laboratory qualitatively agree with those from field experiments. These latter results indicate the feasibility of using laboratory facilities to develop and catalogue spectral signatures of pollutant materials individually and in mixtures.

SECTION 1.4.3. STUDIES AND INVESTIGATIONS

Lewis, B.W.

Relation of Laboratory and Remotely Sensed Spectral Signatures of Ocean-Dumped Acid Wastes

Joint Conference on Sensing of Environmental Pollutants, 4th, New Orleans, Louisiana, November 6-11, 1977

Langley Research Centre (NASA), Hampton, VA 23665

Results of laboratory transmission and remotely sensed ocean upwelled spectral signatures of acid waste ocean water solutions are presented. The studies were performed to establish ocean-dumped acid waste spectral signatures and to relate them to chemical and physical interactions occurring in the dump plume. The remotely sensed field measurements and the laboratory measurements were made using the same rapid-scanning spectrometer viewing a dump plume and with actual acid waste and ocean water samples, respectively. Laboratory studies showed that the signatures were produced by soluble ferric iron being precipitated in situ as ferric hydroxide upon dilution with ocean water. Sea truth water samples were taken and analyzed for pertinent major components of the acid waste. Relationships were developed between the field and laboratory data both for spectral signatures and colour changes with concentration. The relationships allow for the estimation of concentration of the indicator iron from remotely sensed spectral data and the laboratory transmission concentration data without sea-truth samples.

SECTION 1.4.3. STUDIES AND INVESTIGATIONS

Sandness, G.A., et al

Study of Detection, Identification and Quantification Techniques for Spills of Hazardous Chemicals

National Technical Information Service, U.S. Department of Commerce
Battelle, Pacific Northwest Laboratories, Richland, Washington

Department of Transportation, U.S. Coast Guard, Office of Research and Development, Washington, D.C. 20590
October 1976, 188 pages

This study is intended to provide some of the initial technical data needed by the Coast Guard and the EPA for monitoring water pollution in inland and coastal waters. There are two major parts to this report. In the first part, twelve generalized remote and in situ water pollution sensing techniques are identified and discussed. Then the relative potential and current detectability, identifiability, and quantifiability of each of the first 400 chemicals in the Coast Guard CHRIS list are estimated with respect to each of these techniques. The results are presented as numerical matrices or charts. Needs for further research and development of pollution sensing instrumentation are discussed.

The second part of this report describes the design and testing of a prototype, active, aerial scanner system being developed by Battelle-Northwest for nighttime pollution detection. The feasibility of the design concept was demonstrated by laboratory and flight tests of the scanner together with laboratory measurements of the fluorescence spectra of fourteen oils and five other chemicals.

SECTION 1.4.3. STUDIES AND INVESTIGATIONS

Washburn, J.F./Sandness, G.A.

Detection, Identification, and Quantification Techniques for Spills of Hazardous Chemicals

Int. Symp. on Remote Sensing of Environment, Proc., 11th, Vol.II, April 25-29, 1977, ERIM, Ann Arbor, Michigan
April 1977, 7 pages

CCRS No. 1014365

In this study, we have evaluated the first 400 chemicals listed in the Coast Guard's Chemical Hazards Response Information System (CHRIS) handbook with respect to their detectability, identifiability, and quantifiability by 12 generalized remote and in situ sensing techniques and some of the pollution sensing instruments that are currently available or which could reasonably be expected to be available within the next few years. We have also attempted to identify some of the key areas in the technology of water pollution sensing in which additional research and development efforts are needed.

SECTION 1.4.3. STUDIES AND INVESTIGATIONS

Whitte, W.G./Usry, J.W./Whitlock, C.H./Gurganus, E.A.

Laboratory Measurements of Radiance and Reflectance Spectra of Dilute Secondary-Treated Sewage Sludge

Report No. NASA TP-1089, The National Technical Information Service, Springfield, VA 22161
December 1977, 20 pages

A research program was conducted by NASA, in co-operation with EPA and the National Oceanic and Atmospheric Administration (NOAA), to evaluate the feasibility of remotely monitoring ocean dumping of waste products such as acid and sewage sludge. One aspect of the program involves the measurements of upwelled spectral signatures for sewage-sludge mixtures of different concentrations in all 11,600-liter tank; radiance and reflectance spectra in the visible near-infrared ranges at concentrations ranging from 9.7 to 180 PPM of secondarily-treated sewage sludge mixed with two types of base water are given. Results indicate that upwelled radiance varies in a near-linear manner with concentration and that the sludge has a practically flat signal response between 420 and 970 NM. Reflectance spectra were obtained for the sewage-sludge mixtures at all wavelengths and concentrations.

1.5.0. REMOTE SENSING OF SUSPENDED SOLIDS

1.5.1. Airborne Monitoring
- Infrared Imagery
- Spectral Reflectance

1.5.2. Satellite Data - LANDSAT and ERTS

1.5.3. Study and Investigation

SECTION 1.5.1. AIRBORNE MONITORING

Infrared Imagery

Miller, W.F. et al

The Use of Hand-Held 35mm Colour Infrared Imagery for Estimates of Suspended Solids - A Progress Report

Remote Sensing of Earth Resources, 4th Annual, Tullahoma, Tennessee, March 24-26, 1975

Space Inst. University of Tennessee, Tullahoma, TN 37388

Inst. of Environmental Studies, Mississippi, MS 39762
March 1975, 12 pages

CCRS No. 1010757

The Munsell Colour System was utilized in an attempt to correlate total suspended solids, inorganic solids, and organic solids with colour designations. Sixteen catfish ponds were over-flown daily for seven days using two hand-held 35mm cameras with both Kodachrome X and Ektachrome Infrared film. Hue, value and chrome designations were recorded for each pond on each date by three interpreters, and the accepted colour was that recorded by at least two of the interpreters, or if there was a 3 hue range, the median was accepted. The inter-relationships between suspended solids and the colour designations were graphically analyzed; chroma was discarded due to an apparent lack of correlation. Multiple regression was then employed to analyze the data. Highly significant correlations were found between hue and value and total and inorganic suspended solids. Variation in organic solids was apparently too subtle to be detected by the Munsell System. The regressions were of the form, $Y=b_o-b_1$ (In hue) $-b_2$ (Value) $+b_3$ (Value)^2. In addition, organic solids also tend to mask the inorganic solids-colour relationship.

The purpose of this investigation was to apply the previously reported methodology to remotely sensed data that were collected over wastewater sludge plumes in the New York Bight apex on September 22, 1975. Spectral signatures were also determined during this study. These signatures may be useful in the specific identification of sludge plumes, as opposed to those created by the disposal of industrial acid wastes. The work described here was conducted jointly by the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), and the State University of New York (SUNY).

SECTION 1.5.1. AIRBORNE MONITORING

Multispectral Photography

Bressette, W.E.

Aerial Photographic Water Colour Variations from Pollution in the James River

American Cong. on Surveying and Mapping - American Soc. of Photogrammetry, Fall Convention, 1978

American Cong. on Surveying and Mapping, 210 Falls St., Fall Church, VA 22046

Langley Research Centre (NASA), Hampton, VA 23665
October 1978, 19 pages

CCRS No. 1024741

A photographic flight was made over the James River on May 17, 1977. The data show that, in general, James River water has very high sunlight reflectance. In the Bailey Bay area this reflectance is drastically reduced. Also shown is a technique for normalizing off-axis variations in radiance film exposure from camera fall-off and uneven sunlight conditions to the nadir value. After data normalization, a spectral analysis was performed that identifies Bailey Creek water in James River water. The spectral results when compared with laboratory spectro-meter data indicate that reflectance from James River water is dominated by suspended matter, while the substance most likely responsible for reduced reflectance in Bailey Creek water is dissolved organic carbon.

SECTION 1.5.1. AIRBORNE MONITORING

Multispectral Photography

Johnson, R.W. et al

Quantitative Mapping of Suspended Solids in Wastewater Sludge Plumes in the New York Bight Apex

WPCF Journal, October 1977

Lang LPYE Search Centre (NASA), Hampton, VA 23665
October 1977

CCRS No. 1013632

Large quantities of wastewater sludge dredge spoils, industrial wastes and cellar dirt are dumped in the apex of the New York Bight. Little is known about the local dispersion of wastewater sludges plumes and suspended materials include studies on the fate of sludge-derived ammonium in the water column, the fate of wastewater sludge as measured by carbon and nitrogen in sediment samples collected from the wastewater sludge disposal site, and the distribution of suspended material in the water column as measured by an acoustic system. These studies have provided valuable information about both long- and short-term aspects of wastewater disposal at sea, but they are limited by the number of stations that can be sampled in a short time.

Synoptic surface distributions of features such as suspended solids (SS) associated with ocean dumping and the resultant surface plumes may be studied by remote sensing from aircraft and platform. Spectral anomalies have been used to locate and qualitatively map readily identifiable features such as suspended sediments associated with river discharges. Quantitative mapping of the distribution of water quality properties using remotely sensed data has been reported by Johnson, who used a statistical stepwise regression analysis to calibrate remotely sensed data.

SECTION 1.5.2. SATELLITE DATA - LANDSAT AND ERTS

Alfoldi, T.T./Munday, Jr., J.C.

Toward a LANDSAT Water Quality Monitoring System

Canadian Symp. on Remote Sensing, Proc., 4th, May 1977, Quebec City, Quebec

Energy, Mines and Resources Canada, Canada Centre for Remote Sensing
May 1977, 15 pages

CCRS No. 1011906

This investigation is of a chromaticity technique for LANDSAT CCT data analysis which has the potential to be implemented in a water quality monitoring program. The results show that multi-temporal data from LANDSAT-1 and 2 (at high and low-gain) can be analyzed for suspended solids concentration with high precision, and that the data can be transformed into a water quality index. The technique is implemented at CCRS on the General Electric Co., Image-100 multispectral analysis system which permits extremely rapid interactive processing and hardcopy recording of results.

SECTION 1.5.2. SATELLITE DATA - LANDSAT AND ERTS

Alifoldi, T.T./Munday, Jr., J.C.

Water Quality Analysis by Digital Chromaticity Mapping of LANDSAT Data

Canadian Journal of Remote Sensing, Vol.4, No.2, August 1978

Presented at the Canadian Symp. on Remote Sensing, Proc., 4th, Quebec City, Mary 1977

Contribution No. 810, Virginia Institute of Marine Science
August 1978, 19 pages

CCRS No. 1016464

Digital chromaticity analysis of LANDSAT CCT data with the Image-100 system is a rapid and convenient method for investigating water quality. The chromaticity transformation involves ratio normalization by total radiance, which enhances and facilitates water colour monitoring and analysis. Radiance noise of equal proportions in all bands is removed by the chromaticity transformation, and residual chromaticity loci have been defined for pure water, suspended solids, chlorophyll, bathymetry, dry vs. wet sand, snow, ice, air pollution, haze, and clouds of variable thickness. A correlation coefficient of r=.96 (ps.001) has been obtained, after graphical adjustment for varying atmospheric conditions, for multi-date sampling of suspended solids in the Mines Basin, Nova Scotia. A practical LANDSAT IMAGE-100 chromaticity analysis system for water quality monitoring at relatively low cost can now be developed.

SECTION 1.5.2. SATELLITE DATA - LANDSAT AND ERTS

Amos, C.L./Alfoldi, T.T.

The Determination of Suspended Sediment Concentration in a Microtidal System Using LANDSAT Data

Journal of Sedimentary Petrology, Vol.49, No.1, March 1979

The distribution and transport of suspended sediments in the Bay of Fundy are extremely difficult to define because of the high tidal range and resulting high time variability in sediment distribution. The spatial distribution of suspended sediments have been mapped using LANDSAT Imagery. During a period of two years a field verification program has been underway to relate multispectral seawater radiance recorded digitally by LANDSAT 1 and 2 to the absolute surface suspended sediment concentration. A correlation of 0.96 has been established for the two variables for multi-temporal data for a variety of sediment types. Thematic maps generated from clear LANDSAT imagery can be used quantitatively to determine circulation patterns, sources of material, and volumes of suspended sediment for the local region. Initial results suggest that the calibration may be applied to any marine environment similar to Minas Basin and is valid for a variety of sediment sizes, shapes and composition.

SECTION 1.5.2. SATELLITE DATA - LANDSAT AND ERTS

Brooks, D.J.

LANDSAT Measures of Water Clarity

Photogrammetric Engineering and Remote Sensing, Vol.41, No.10, October 1975, pp.1269-1272

General Electric Company, Beltsville, MD 20705
October 1975, 4 pages

Comparison of in-situ transmittance and LANDSAT reflectance data reveal a negative straight-line relationship for the values encountered. Such a treatment and result differ from previous work in that in-situ transmittance is an objective field measure of water clarity. This is significant since it supports and extends existant evidence that the changing character of water clarity can be effectively monitored using LANDSAT-type data.

SECTION 1.5.2. SATELLITE DATA - LANDSAT AND ERTS

Feely, R.A./Lamb, M.F.

A Study of the Dispersal of Suspended Sediment from the Fraser and Skagit Rivers into Northern Puget Sound Using LANDSAT Imagery

National Oceanic and Atmos. Admin., Environ. Research Lab., Pac. Mar. Environ Lab., 7600 Sand Point Way N.E. Seattle, WA 98115, U.S. Interagency Energy-Environ. Research and Development Program Rep. U.S. Department of Commerce, U.S. Environ. Prot. Agency, Office of Energy, Minerals and Ind., Washington, DC 20460, U.S. EPA-600/7-79-165

February 1979, 46 pages

LANDSAT images, obtained during the period between 1972 and 1978, have been utilized to study the surface trajectories of sediment plumes originating from the Fraser and Skagit Rivers. These plumes are natural tracers of flow patterns of low salinity water and suspended matter that is discharged into northern Puget Sound from these rivers. Three separate plumes can be observed emanating from the tributaries of the Fraser River. The plumes from the Main Arm and Middle Arm join together to form a well-defined jet which can be traced across the Strait of Georgia and through Porlier, Active, and Boundary Passes. During ebb tide the plume is directed to the southeast from a point about midway between Steveston and Porlier Pass. The flood tide drives the plume across the Strait and to the northwest along the northern coast of Galiano Island. The presence of a well-defined jet is indicative of the significance of longitudinal pressure and internal forces. The plume from North Arm moves to the northwest past Point Grey where it bifurcates, with some material flowing to the northwest during ebb tide and the remaining material moving into Burrard Inlet. The northward flow of the plume from the North Arm is probably the result of a combination of a number of forces including inertial, pressure and coriolis. The existence of a number of separate plumes in some of the images suggests that eddies of sediment-laden water are probably capable of maintaining their identify for periods longer than a single cycle. This implies that a dynamic balance exists between the inertial and pressure forces associated with these boluses, and the coriolis and tidal forces associated with circulation patterns in the Strait.

SECTION 1.5.2. SATELLITE DATA - LANDSAT AND ERTS

Klemas, V.

Satellite Studies of Turbidity, Waste Disposal Plumes and Pollution-Concentrating Water Boundaries

Environmental Quality Sensors Conference, 2nd, Proc., October 10-11, 1973, Las Vegas

U.S. Environmental Protection Agency, 401 M St., S.W., Washington DC 19711 October 1973, 32 pages

CCRS No. 1008719

Satellite imagery from four successful ERTS-1 passes over Delaware Bay during different portions of the tidal cycle are interpreted with special emphasis on visibility of turbidity patterns, acid disposal plumes and convergent water boundaries along which concentrations of pollutants have been detected. The MSS red band (band 5) appears to give the best contrast, although the sediment patterns are represented by only a few neighbouring shades of grey. Colour density slicing improves the differentiation of turbidity levels. However, colour additive enhancements are of limited value since most of the information is in a single colour band. The ability of ERTS-1 to present a synoptic view of the turbidity and circulation patterns over the entire bay is shown to be a valuable and unique contribution of ERTS-1 to both coastal ecology and coastal oceanography.

SECTION 1.5.2. SATELLITE DATA - LANDSAT AND ERTS

Munday, Jr., J.C./Alfoldi, T.T./Amos, C.L.

Verification and Application of a System for Automated Multidate LANDSAT Measurement of Suspended Sediment

W.T. Pecora Symposium on Satellite Hydrology, Sioux Falls, South Dakota, June 11-14, 1979

Contribution No. 909, Virginia Inst. of Marine Science

A system has been implemented for automated multidate LANDSAT CCT MSS measurement of suspended sediment concentration "S", and verified on nine sets (108 points) of S data from the Bay of Fundy, Canada. The system employs "chromaticity analysis" to provide automatic pixel-by-pixel adjustment of atmospheric variations, permitting reference calibration data from one or several dates to be spatially and temporarily extrapolated to other regions and to CCT's from other dates. Correlation between a LANDSAT "chromaticity coefficient" and $\log_e S$ was $r=0.965$, which produced a mean standard error of prediction of 30% of S. For verification, each data set was used in turn as test data against the remainder as a calibration set: the average absolute error was 44% of S over the range $1<S<1000$ mg/ℓ. Effect of sediment type and size, and solar angle, were found negligible. Solar angles near the Brewster angle may introduce noise. The system can be used to measure chlorophyll (in the absence of atmospheric variations), Secchi disc depth, and turbidity. The system was applied to the Fundy Tidal Power Project. S contour maps were used to initialize and calibrate a numerical model, and were also interpreted in order to define sediment transport paths and hydrodynamic flow. Results indicate that no significant sedimentation is expected from the proposed Fundy tidal barrage during its design lifetime.

SECTION 1.5.2. SATELLITE DATA - LANDSAT AND ERTS

Scherz, J.P./Van Domelen, J.F.

Lake Superior Water Quality Near Duluth from Analysis of Aerial Photos and ERTS Imagery

Remote Sensing and Water Resources Association

American Water Resources Association, Proc., No.17, Urbana, Illinois
June 1973, pp.147-160

ERTS imagery of Lake Superior in the late summer of 1972 shows dirty water near the city of Duluth. Questions that arose when these photos were examined were: What water quality parameters correlate with this tone, and how can these parameters be practically and reliably obtained from analysis of the ERTS imagery? To make a correlation it was first necessary to do low altitude aerial photography while simultaneously sampling the water at selected points. Water samples and simultaneous photographs were taken on three separate days following a heavy storm which caused muddy run-off water. The water samples were analyzed for turbidity, colour, and solids. Reflectance and transmittance characteristics of the water samples were determined with a spectrometer apparatus. The same apparatus attached to a microdensitometer was used to analyze the photographs for the approximate colors or wavelengths of reflected energy that caused the exposure. It was observed that other parameters of turbidity correlate with the aerial imagery on all days, as the character of the dirty water changes due to settling and mixing. Aerial photographic imagery is indeed a valuable engineering tool for overall water quality investigations and should be used as such.

SECTION 1.5.2. SATELLITE DATA - LANDSAT AND ERTS

Strong, A.E./Eadie, B.J.

Satellite Observations of Calcium Carbonate Precipitation in the Great Lakes

Limnology and Oceanography, Vol.23, No.5, September 1978, p.877

U.S. NESS, Washington DC 20233
September 1978, 11 pages

CCRS No. 1017316

Reflectance patterns apparently from Calcium Carbonate ($CaCO_3$) precipitation have been mapped in the Great Lakes using satellite multispectral imagery. The milky water phenomenon (whiting) occurred regularly in summer and fall during the period studied, 1972-1975, in Lake Ontario, Erie and Michigan but not in Superior and Huron. In situ data provide nearly irrefutable evidence that these whitings are calcareous. They are attributed to supersaturation of $CaCO_3$ during periods of thermal stratification and are most intense in the warmer areas of the lakes. The whitings are maximal several meters below the surface and are undoubtedly significant with respect to light transmission, affecting the euphotic zone and thereby photosynthetic production. They may serve as lakewide markers in synoptic analysis of large-scale epilimnial horizontal motions.

SECTION 1.5.2. SATELLITE DATA - LANDSAT AND ERTS

Sydor, M.

Analysis of Suspended Solids in Lakes Using LANDSAT Multispectral Data

Canadian Journal of Spectroscopy, Vol.23, No.3, May/June 1978, p.91-97

University of Minnesota, Dept. of Physics, Duluth MN 55812
June 1978, 7 pages

CCRS No. 1016435

A set of criteria are given for using LANDSAT data for identification of three categories of particulate contaminants in Lake Superior. A linear transformation giving the relationship between the residual LANDSAT intensities and concentrations of the three contaminants was obtained from correlation of remote sensing data with in situ measurements. The inverse transformation gives the concentration of particulates in terms of the multispectral signal intensities. This paper discusses the dependence of volume reflectance on contaminant concentrations and presents the rudiments for selection of optical signatures for identification of suspended solids in lakes.

SECTION 1.5.2. SATELLITE DATA - LANDSAT AND ERTS

Sydor, M./Stortz, K.R./Swain, W.R.

Identification of Contaminants in Lake Superior Through LANDSAT-1 Data

Journal of Great Lakes Research, Vol.4, No.2, June 1978, pp.142-148

Int. Assoc. Great Lakes Research, State University College, Buffalo, NY 14222

University of Minnesota, Dept. of Physics, Duluth, MN 55812
June 1978, 7 pages

CCRS No. 1023133

Remote sensing signatures were developed for using LANDSAT data in identification of four types of particulate contaminants in Lake Superior. The criteria are based on the residual LANDSAT signal intensities and signal ratios. The signatures work well in differentiation of river run-off from high background turbidity due to erosion and resuspension. The threshold concentration for identification of suspended solids in lakes ranges in the order of 1 mg/L for clear lakes such as Lake Superior and 5 mg/L for light absorbing water characteristics of the Duluth-Superior Harbour.

SECTION 1.5.2. SATELLITE DATA - LANDSAT AND ERTS

Watanabe, K.

Polluted and Turbid Water Masses in Osaka Bay and its Vicinity Revealed with ERTS-A Imageries

Symposium on Significant Results .... from ERTS-1, Proc., New Carrollton, MD/Vol. 1-A/p.681

NASA Goddard Space Flight Carter/NASA SP-237

Kyoto Gakuen University, Kyoto, Japan
March 1973

CCRS No. 1003057

The heavy water pollution is one of the most serious problems in Osaka Bay and its vicinity. However, the state of water pollution there has never been monitored in the scale of the whole Osaka Bay because the conventional point to point observations make it impossible to detect the periodical movement of water masses by the fairly strong tidal current.

ERTS-A took very valuable MSS imageries of Osaka Bay and its vicinity on October 24, 1972. In the MSS-4 and MSS-5 imageries a complex grey pattern of water masses can be seen. Though some of the grey-coloured patterns seen in black and white prints of the MSS-4 and MSS-5 imageries are easily identified from their shapes as cloud cover or polluted water masses characterized by their colour tone in longer wavelenths in the visible region, any correct distribution pattern of polluted or turbid water masses can hardly be distinguished from thin cloud cover in a quick-look analysis.

In the present investigation, a simple photographic technique was applied, using the fact that reflected sunlight from clouds (including smog), and inclined water surfaces of waves have a certain component in the near infrared region, that is MSS-7 but has only the green and yellow component sensible in MSS-4 and MSS-5 channels. That is, combined prints were made from positive imagery of MSS-4 or 5 together with negative imagery of MSS-7 using a photographic enlarger. In such combined prints, areas of clouds and smog show as white or lighter grey, whereas polluted or turbid water masses are clearly represented with black or darker grey tones.

SECTION 1.5.3. STUDIES AND INVESTIGATIONS

Blanchard, B.J./Learner, R.W.

Spectral Reflectance of Water Containing Suspended Sediments

Remote Sensing and Water Resources Management

American Water Resources Association, Proc., No.17, Urbana, Illinois
June 1973, pp.334-347

A spectral radiometer, measuring radiation in the visible and near-infrared portion of the spectrum, was used to examine (1) different concentrations of red, black and grey clay particles in water, and (2) several samples of natural pond water containing sediment. Four of the pond samples had algae present. Density m easurements were made of colour and colour infrared film photographs of the samples exposed at the same time as the radiometer measurements. Reflectance curves in the near-infrared region show very little change caused by changing sediment concentrations. However, reflectance curves in the visible portion of the spectrum are sensitive to very low concentrations (less than 200 ppm suspended solids) of sediment with similar characteristics. The samples containing algae showed a good possibility of detecting algae by comparing the reflectance near wavelength 570 nm with the reflectance at 680 nm. Response at 570 nm appears to be related to suspended sediment. Results using the film density measurements also show promise for use in estimating low sediment concentrations; however, the best combination of film and filter are not known for different sediment characteristics.

SECTION 1.5.3. STUDIES AND INVESTIGATIONS

Kleeman, C.L.

Sediment Pollution and Applied Remote Sensing

Urban Hydrology, Hydraulics and Sediments Control, Int. Symp., Proc., Lexington, Kentucky, July 18-21, 1977, pp.295-301

U.S. Environmental Protection Agency, Philadelphia, PA 19106
July 1977, 7 pages

CCRS No. 1021377

Applications of photographic remote sensing have been found useful for locating and monitoring various sediment-related forms of stream and waterway pollution. Orbital remote sensing photography and imagery and aerial photography of various altitudes and film types were studied by visual interpretation for use in detection of waterborne sediment.

SECTION 1.5.3. STUDIES AND INVESTIGATIONS

Klooster, S.A./Scherz, J.P.

Water Quality by Photographic Analysis

University of Wisconsin, Madison

Photogramm. Eng., Vol.40, No.8
August 1974, 9 pages

A positive correlation exists between reflectance of water and the water quality parameter of turbidity. This relationship holds for all times for a particular waste. At particular times other parameters such as suspended solids correlate to turbidity and can also be mapped. To analyze aerial photos properly to obtain water reflectance, a standard reflectance panel is needed somewhere in the frame. For this study, colour and colour-infrared film were used and analyzed with a colour microdensitometer which, with certain modifications, is also used to analyze reflectance of water samples. Noise in the analysis includes bottom effects, reflection from the air-water interface, and path luminance, but these can all be dealt with by proper techniques.

SECTION 1.5.3. STUDIES AND INVESTIGATIONS

Schiebe, F.R./Ritchie, J.C.

Colour Measurements and Suspended Sediments in North Mississippi Reservoirs

Remote Sensing of Earth Resources Conferences, 4th Annual, Tullahoma, Tennessee, March 24-26, 1976

Space Inst., University of Tennessee, Tullahoma, TN 37388

U.S. Agricultural Research Service, Sedimentation Lab., Oxford, MS 3865
March 1976

CCRS No. 1010761

The solar radiation spectra reflected from North Mississippi reservoirs have been analyzed according to the CIE system for the quantitative description of colour. This analysis results in the determination of trichromatic coefficients which when plotted on a chromaticity diagram yield a dominant wavelength of colour and the colour purity. These parameters have been related to in situ measurements of suspended sediments in North Mississippi reservoirs. A quantitative relationship was determined for concentrations of suspended sediments in the range 15 ppm $< Cs <$ 100 ppm.

SECTION 1.5.3. STUDIES AND INVESTIGATIONS

Sheives, T.C./Rouse, J.W./Mayo, W.T.

Remote Measurement of Water Pollution with a LIDAR Polarimeter

Int. Symp. on Remote Sensing of Environment. 9th., Ann Arbor, Michigan, April 15-19, 1974

Environmental Research Institute of Michigan, Ann Arbor, MI 48107

Remote Sensing Centre (Texas A&M University), College Station
April 1974, 14 pages

CCRS No. 1005077

This paper examines a dual polarization laser backscatter system as a method for remote measurement of certain water quality parameters. Analytical models for describing the backscatter from turbid water and oil on turbid water are presented and compared with experimental data. Laser backscatter field measurements from natural waterways are presented and compared with simultaneous ground observations of the water quality parameters: turbidity, suspended solids, and transmittance. The results of this study show that analytical models appear valid and that the sensor investigated is applicable to remote measurement of these water quality parameters and oil spills on water.

1.6.0. REMOTE SENSING OF PHYTOPLANKTON - CHLOROPHYLL

1.6.1. Airborne Monitoring

- Light Detection and Ranging (LIDAR)
- Scene Colour Standard (SCS)
- Multichannel Ocean Colour Sensor (MOCS)

1.6.2. Satellite Data - LANDSAT

SECTION 1.6.1. AIRBORNE MONITORING

LIDAR System

Jarrett, Jr., O./Mumola, P.B./Brown, Jr., C.A.

Four Wavelength LIDAR Applied to Determination of Chlorophyll A Concentration and Algae Colour Group

Remote Sensing and Water Resources Management

American Water Resources Association, Proc., No.17, Urbana, Illinois June 1973, pages 259-269

A technique for remote measurement of chlorophyll a density and determination of algae colour group is described. In vivo fluorescence measurements of chlorophyll a for four colour groups of algae; green, golden, golden-brown, red and blue-green are described and representative spectra are shown. The LIDAR equation is developed for the general case of a mixture of colour groups showing the need for multicolour excitation. The LIDAR instrument which has been designed and fabricated at Langley Research Centre for helicopter flights over surrounding portions of the Chesapeake Bay is described. The LIDAR package contains a unique four-colour dye laser which permits multicolour excitation of chlorophyll a fluorescence from the various colour groups

SECTION 1.6.1. AIRBORNE MONITORING

Scene Colour Standard Technique

Piech, K.R./Walker, J.E.

Aerial Colour Analysis of Water Quality

American Society of Civil Engineers, Meeting, January 1971, Phoenix, AZ

Cornell Aeronautical Lab., Inc., P.O. Box 235, Buffalo, N.Y. 14221
January 1971, 27 pages

CCRS No. 1004663

Aerial surveys of water quality have been restricted almost exclusively to qualitative or semi-qualitative observations of relatively large scale effects. This has been due to the inability to remove a number of peripheral effects masking the true volume spectral reflectance and to some extent to the inability to interpret VSR in terms of water quality parameters. This paper discussed the basic physical phenomena behind these peripheral effects and introduced a newly developed technique, called the scene colour standard (SCS) technique that allows for removal of these peripheral effects in water quality surveys. The procedure using the SCS technique for accurate measurement of the three parameters that described peripheral effects, as an example a measurement program conducted to assess limnetia chlorophyll content in Chautauqua Lake in New York State, have been discussed.

SECTION 1.6.1. AIRBORNE MONITORING

Multispectral Imagery

Grew, G.W.

Remote Detection of Water Pollution with MOCS : An Imaging Multispectral Scanner

Environmental Quality Sensors Conference, 2nd, Proc., October 10-11, 1973

U.S. Environmental Protection Agency, 401 M St.,S.W., Washington D.C., 20460

Langley Research Centre (NASA), Hampton, VA 23665
October 1973, 24 pages

CCRS No. 1008695

Aircraft flights to collect spectral data using MOCS (Multichannel Ocean Colour Sensor) are being conducted in an effort to establish algorithms which correlate with and distinguish between water pollutants, including algae and sediment. Data collected over Clear Lake, California, New York Bight, and off Cape Hatteras demonstrate the value of MOCS as a remote sensing tool in studying the hydrosphere. A spectral signature extracted from the Clear Lake data has identified the types of algae in the lake. The New York Bight and Cape Hatteras data reveal a peculiar signature associated with the transition from blue water to a turbid water mass. This transitional signature may be useful as a calibration point for remotely determining the concentrations of suspended materials in the surrounding waters.

SECTION 1.6.2. SATELLITE DATA - LANDSAT

Hellden, V./Akersten, I.

LANDSAT Digital Data for Water Pollution and Water Quality Studies in Southern California

Int. Symp. on Remote Sensing, 11th Proc., Ann Arbor, MI.
April 25-29, 1977

ERIM, P.O. Box 618, Ann Arbor, MI 48107

University of Lund, Department of Physical Geography, Solvegaton 13, S-23361, Lund, Sweden
April 1977, 10 pages

CCRS No. 1014299

Spectral diagrams, illustrating the spectral characteristics of different water types, were constructed by means of simple statistical analysis of the various reflectance properties of water areas in southern Scandinavia as registered by LANDSAT-1. There were indications that the measured spectral reproduction is dominated by chlorophyllous matter. Differences between lakes, as well as the patchiness of individual lakes, concerning secchi disc transparency could be visualized after classification and reproduction in black and white and in colour by means of Line Printer, Calcomp Plotter (CRT) and Ink Jet Plotter, respectively.

SECTION 1.6.2. SATELLITE DATA - LANDSAT

Lawrence, G.R./Graham, C.W.

Remote Sensing Applied to Algal Problems in Lakes

Canadian Symposium on Remote Sensing, 3rd, Sept.22-24, 1975, Edmonton, Alberta

Ontario Centre for Remote Sensing, (Ministry of Natural Resources)
Toronto, Ontario
September 1975

CCRS No. 1006409

As public awareness of ecological problems increases, planners are becoming more conscious of the impact of their proposals on the environment. Consequently, it is becoming imperative that plans for lake development be devised on the basis of existing and anticipated biological conditions. Although a complete assessment of the ecology of an area would require extensive in situ investigation, certain of the critical aquatic and terrestrial parameters may be evaluated through the use of remote sensing techniques. In view of the complexity of such an analysis, however, this paper will be directed toward a single aspect of such a study - monitoring algal conditions in lake surface-waters.

In comparison to the restricted perspective obtained during in situ investigations, remote sensing provides a complete overview for the mapping of surface distribution of algal blooms and for selection of sampling areas. The spectral reflectance of surface algae in the near infrared portion of the spectrum provides the necessary signature for photographic analysis.

A case study for Lake of the Woods (Ontario) is presented. High surface concentrations of algae on this lake provide spectral signatures that have been recorded by the multispectral scanner of the LANDSAT-1 satellite. Electronic density analysis of this imagery distinguishes relative algal concentrations and distributions that are substantiated by low-altitude colour infrared photography.

1.7.0. REMOTE SENSING OF THERMAL DISCHARGES

1.7.1. Airborne Remote Sensing
- Infrared Imagery

1.7.2. Studies and Investigations

SECTION 1.7.1. AIRBORNE REMOTE SENSING

Infrared Imagery

Fang, C.S. et al

An Estuarine Thermal Monitoring Program : Progress in Astronautics and Aeronautics; Thermal Pollution Analysis, Vol.36, 1975, p.241

AIAA, 1290 Avenue of the Americas, New York, NY 10019

Virginia Inst. of Marine Science, Dept. of Physical Oceanography and Hydraulics, Gloucester Point, VA
xxx 1975

CCRS No. 1009571

A monitoring program has been designed and operated to measure environmental parameters for a waste heat study of the 1700 megawatt Surrey Nuclear Power Plant located on the James River in Virginia. Monitoring techniques include a moving boat system, a stationary tower system, and aerial infrared scanner images of the study area. Data acquired from this program are used in a waste heat study, indicating the state of the environment before and after the power station became operational. The pre-operational data indicate a consistent seasonal pattern of monthly averages of temperature and salinity over two years 1971 and 1972, the 1972 averages being slightly lower as a result of unusual rainfall. Data from the first year of operation (1973) show significant temperature and salinity increases over both comparable pre-operational periods.

SECTION 1.7.1. AIRBORNE REMOTE SENSING

Infrared Imagery

Marmer, G.J./Toker, J.V./Madding, R.P.

Comparison of Thermal Scanning and In-Situ Techniques for Monitoring Thermal Discharges

Water Resources Bulletin, Vol.II, No.6, p.1157-1180
December 1975, 24 pages

Two methods of measuring the behaviour of thermal plumes were compared by application to plumes at Point Beach nuclear power plant on Lake Michigan. The classical in situ method, which employs surface and subsurface Thermistor probes extended from a boat, whose position is determined by a microwave ranging system, was contrasted with a remote sensing technique which utilizes an aircraft-mounted infrared scanner operating in the B-14 micron range. Principal characteristics of plume description were isothermal configurations, areas contained within isotherms, and centreline temperature decay. The in-situ method was slow and subject to effects of external forces over the test period, and it required interpolative judgement to generate isotherms; but it did provide information on subsurface as well as surface temperatures. Thermal scanning produced a considerably more detailed picture of subsurface temperature, but it was subject to distortion by surface skin effects during extremely calm conditions. Good agreement between the methods was found on four or five occasions; the fifth instance was a case of quiescent conditions distorting the result of thermal scanning. It was proposed that the methods be used jointly to achieve the best possible picture of thermal plume behaviour.

SECTION 1.7.1. AIRBORNE REMOTE SENSING

Infrared Imagery

N.Y. State Atomic and Space Development Authority, New York

A Survey of New York Surface Water Temperatures. Aerial Infrared Surveys of Thermal Discharges from Electric Generating Stations into New York State Waters

National Technical Information Service, Springfield, VA 22161

Thermal discharge plumes were measured by aerial infrared sensing techniques at four power stations on the Hudson River: Albany, Danskammer Point, Indian Point and Lovett. Infrared images and related temperature contour maps are included in the report. These indicate that the effects observed include tidal currents, local counter-currents, recirculation of discharged water, thermal striation, and mixing. The capability of the infrared method to fill the current need for quantitative data with broad synoptic coverage is illustrated.

SECTION 1.7.1. AIRBORNE REMOTE SENSING

Infrared Imagery

Ryan, P.J./Stolzenback, K.D./Elder, R.A.

Water Temperature Monitoring by Thermal Scanning

Remote Sensing of Earth Resource, 2nd Annual Conference, Tullahoma, Tennessee, March 26-28, 1973, p.113

Tennessee Valley Authority Engineering Laboratory, Norris, Tennessee March 1973, 9 pages

CCRS No. 1003509

Airborne infrared surveys may be used to determine water surface temperatures rapidly over large areas; however, the radiation reaching the detector may not be indicative of bulk water temperatures due to surface skin effects, subsurface stratification, reflected sky radiation and atmospheric attenuation. The quantitative capability of such surveys depends on the precision with which these effects can be estimated. The findings of previous investigations, and recent experience by TVA, indicate that errors in the determination of water temperatures may be reduced, but not eliminated, by applying computed or observed corrections.

SECTION 1.7.1. AIRBORNE REMOTE SENSING

Infrared Imagery

Scarpace, F.L./Green, T.

Dynamic Surface Temperature Structure of Thermal Plumes

Water Resources Research, Vol.9, No.1, Feb. 1973, p.138

Inst. for Environmental Studies, University of Wisconsin, Madison WI 53706
February 1973, 16 pages

CCRS No. 1018187

Airborne thermal imagery is used to show that thermal plumes often vary rapidly in space and time, although both the initial thermal effluent and the receiving water change very little. The imagery is buttressed by simultaneous data taken from boats. The rapid variations can cast doubt on the validity of some standard methods of measuring thermal plumes. The plume is shown to be sometimes dominated by a series of concentric thermal fronts that spread radially outward from the outfall. These are described, and various tentative explanations for their occurrence are given.

SECTION 1.7.1. AIRBORNE REMOTE SENSING

Infrared Imagery

Stingelin, R.W./Avis, G.B.

Digital Processing Techniques in Thermal Plume Analysis

Remote Sensing and Water Resources Management

American Water Resources Association, Proc., No.17, Urbana, Illinois
June 1973, pp.299-310

The Reconofax XVI airborne scanning radiometer is used to collect infrared data of the thermal plume from the Connecticut Yankee Nuclear Power Plant. Operational in the 8-12 micrometer region, the system uses two controllable black-body reference sources to provide calibrated data on analog magnetic tape. The analog tapes are subsequently digitized in a signal processing facility using 256 8-bit byte, high shift register with the output being digital magnetic tapes. Quantization of the infrared signals is in 64 level, with digitization and storage occuring in blocks of 256 data words per scan line including black-body sample pulses. Analysis and display of the infrared data is accomplished through use of a Computek interactive graphic system attached to a digital computer. Data may be displayed in a variety of ways, including grey shades, isotherm maps, and radiometric profiles. Analytical computer routines may be run with the data to perform statistical analysis, scene correction, residual analysis and thermal modeling. Thermal modeling of plume data collected in July 1972 is attempted for four tidal stages of the Connecticut River. A multiple regression computer routine is used to generate a first-cut, three dimensional model of the plume.

SECTION 1.7.1. AIRBORNE REMOTE SENSING

Infrared Imagery

Van Lopik, J.R./Rambie, G.S./Pressman, A.E.

Pollution Surveillance by Non-Contact Infrared Techniques

Water Pollution Control Fed., Coden : JWPF-A, Vol.40, No.3, p.425
March 1968

Texas Instruments Inc., Dallas, Texas
October 1967, 14 pages

CCRS No. 1000562

This paper concerns the use of airborne infrared mapping systems in the measurement and delineation of thermal pollution and theoretical aspects of non-contact determination of pollutant type, concentration and distribution. Discussions are focussed on the 4 to 14 micrometer portion of the infrared spectrum.

SECTION 1.7.1. AIRBORNE REMOTE SENSING

Infrared Imagery

Wood, E.D.

Delineation of Thermal Effluents Discharged into Tropical Waters Around Puerto Rico by Aerial Infrared Scanning

The American Society of Limnology and Oceanography, 38th Annual Meeting, Halifax, Nova Scotia, June 23-26, 1975
June 1975, 28 pages

Aerial infrared scanning offers a versatile tool with which to monitor thermal discharges and a rapid method of detecting extraneous discharges whose temperatures differ from the ambient waters. Knowledge of the extent and distribution of thermal effluents is necessary to assist in determining the effects of the added heat upon biota of the region. An AGA Model 680 Thermovision Infrared Scanner with a 45 degree lens was mounted in a CESSNA 182 and flown at altitudes of 600-2,000 M. during night and twilight hours. The detector was INSB, cooled with liquid nitrogen and sensitive to the range 2-5.6 micrometers. The picture was originally displayed on a colour monitor which assigned ten arbitrary colours to shades of gray on the control unit. Isotherms have been assigned based on simultaneous surface measurements made with a thermometer, read to the nearest 0.1°C. The data were then recorded on film. Ranges were set at 2°C and 0.5°C, respectively. More recently, the data have been recorded on magnetic tapes with a SABRE III instrumentation tape recorder. Observed data were compared to predictions made using the Pritchard plume model. Anomalies can be explained by boundary, wind and tidal effect.

SECTION 1.7.2. STUDIES AND INVESTIGATIONS

National Field Investigation Centre, Denver, Colorado

Remote Sensing Report, Lake Ontario. A Study of Thermal Discharges from Ginna Nuclear Power Station, Oswego Steam Power Station and Nine Mile Point Nuclear Power Station

National Field Investigation Centre, Denver, Colorado
April 1975, 88 pages

PB-255 591/OST

An airborne remote sensing study of thermal discharges into Lake Ontario, from power plants on its southeast shore, was conducted.

Thermal infrared imagery of the lakeshore in the vicinity of the three existing plants was obtained with the thermal channel of an internally calibrated multispectral scanner mounted in a search aircraft. During its flight, water temperatures were measured at the three power plants by ground crews. The airborne imagery and water temperature data were used to characterize the recorder thermal fields or plumes.

SECTION 1.7.2. STUDIES AND INVESTIGATIONS

National Field Investigation Centre, Denver, Colorado

Remote Sensing Study of Steam-Electric Power Plant Thermal Discharges to Lake Erie and the Detroit and St. Clair Rivers - Ohio and Michigan
National Field Investigation Centre, Denver, Colorado

Envir. Protection Agency, Chicago, Illinois, Region V
March 1974, 98 pages

PB-256 939/OST

An airborne remote sensing study of thermal discharge to Lake Erie and Detroit and St. Clair Rivers was conducted on July 9, 1973. The study area encompassed the southern shore of Lake Erie from about 5 km (3 miles) east of Ashtabula, Ohio to Toledo (Maumee Bay), Ohio and the western shore of Lake Erie from Toledo to the mouth of the Detroit River. The western shores of the Detroit and St. Clair Rivers were also included in the study area. Thermal infrared imagery of the entire study area was obtained using infrared line scanners mounted in high performance reconnaisance aircraft. Ground measurements of the water temperature were made at most of the power plants. This imagery and the ground truth water temperature data were used to characterize the observed thermal fields or plumes.

Study technique for thermal discharges includes data interpretation, page 17-24.

SECTION 1.7.2. STUDIES AND INVESTIGATIONS

National Field Investigations Centre

Remote Sensing Study of Thermal Discharges to Lake Michigan, Wisconsin, Illinoi, Indiana and Michigan

National Field Investigation Centre, Denver, Colorado
PB 214 503
September 1972, 64 pages

CCRS No. 2003447

An aerial reconnaissance study was conducted along pre-designated segments of the shoreline of Lake Michigan on September 14, 1972. The purpose of this remote sensing study was to document the extent of thermal discharges from the major electric power plants over the area extending from Muskegon, Michigan to Twin Creeks, Wisconson. A total of ten power stations were in operation at the time of flight while three others were not in operation.

SECTION 1.7.2. STUDIES AND INVESTIGATIONS

EPA, Denver, Colorado, National Field

Remote Sensing Study of Electric Generating Station Thermal Discharges to Barnegat Bay and Great Egg Harbour, New Jersey.

The National Technical Information Service, Springfield, VA 22161

EPA Office of Enforcement, Report No.EPA-330 3-73-003
September 1973, 84 pages

An aerial remote sensing study of thermal discharges to New Jersey coastal waters from two large thermal-electric generating stations was conducted on July 13, 1973. The study encompassed the Great Egg Harbour Bay and the central portion of Barnegat Bay. Thermal discharges evaluated were from the Oyster Creek Nuclear generating station. This study has shown that remote sensing techniques could be implemented into a compliance monitoring program to quickly and cost-effectively ascertain the real time behaviour of thermal discharges and the resultant thermal plumes. A procedure could readily be developed to apply the aerial thermal data to each discharge to document compliance or non-compliance with water quality standards and to evaluate the effectiveness of proposed effluent (thermal) guidelines.

SECTION 1.7.2. STUDIES AND INVESTIGATIONS

Doyle, M.J. Jr.,/Cayot, R.F.

Thermal Power Plant Environmental Studies, Coastal Engineering, Chapt.118

Department of Engineering Research, Pacific Gas and Electric Co.,
Emeryville, California
xxx 1971, 15 pages

CCRS No. 1017923

Once-through cooling water systems for thermal power plants offer an economical means of dissipating the differential energy of modern-day turbines.

Before the decision to proceed with the design of a once-through cooling water system is made, a considerable study effort must be undertaken in order to determine that no harmful effects will accrue to the environment from the plant's operation. These studies must include:

1. A comprehensive literature search
2. Field investigations of the air and water
3. Analytical evaluation of the field data

The Pacific Gas and Electric Company has been conducting environmental studies at its operating thermal power plants and at proposed sites since 1958.

This paper describes the approach used by the Company in conducting environmental studies. Meterological data were obtained from on-site sensors, stored on magnetic tape, and subsequently computer-processed. Oceanographic data in the form of water temperatures, salinity and dissolved oxygen profiles, as well as current speed and direction, were obtained from surface vessels. Remote sensing systems were used to obtain dispersion and dilution information, sea-surface temperature data, and aerial photographs of flora indigenous to the study area. All remote-sensed data, except for the aerial photographs, were stored on magnetic tape, in flight, and later processed in the computer with graphic off-line printout.

SECTION 1.7.2. STUDIES AND INVESTIGATIONS

Veziroglu, T.N./Lec, S.S.

Feasibility of Remote Sensing for Detecting Thermal Pollution, Part I : Feasibility Study, Part 2 : Implementation Plan

Miami University, Coral Gables, Florida, Department of Mechanical and Industrial Engineering
December 1973, 184 pages

N75-15199 3ST

Heated waters from power plants discharged into rivers, lakes and estuaries can cause thermal pollution, thereby disturbing the ecological balance by increasing the temperature levels and causing turbidity. The problems associated with thermal pollution are compounded by recent trends of building more and larger nuclear power plants in order to meet the growing energy demand. It therefore becomes important to have the capability to detect thermal pollution and to be able to alleviate it. The first part of the report covering the feasibility study, indicates that (1) using passive remote sensing methods, it is possible to detect water surface temperatures within plus or minus one degree with a resolution of 0.3 mile radius from spacecraft, and resolution is improving with time, (2) using active remote sensing methods, techniques and instruments could be developed for remote sensing of vertical temperature and turbidity distribution in oceans, and (3) it is feasible to develop a generalized three dimensional model to predict the motion, temperature and salinity of thermal plumes within water to which they are discharged. The second part of the report, covering the implementation plans, include (a) the development and testing of a universal analytical model to predict three-dimensional temperature and salinity distributions in coastal regions receiving hot discharges, (b) improving the accuracy of thermal remote sensing systems by directly relating them to thermal radiation from the sea surface and by better accounting for the absorption in the atmosphere, and (c) the development and testing of an active remote sensing system to measure the water turbidity.

SECTION 1.7.2. STUDIES AND INVESTIGATIONS

Zaitzeff, J.B./Whitehead, V.S.

A Program to Assess a Thermal Discharge on Trinity Bay, Texas

Earth Resources Program Review, Proc., 4th, Houston, Texas, January 17-19, 1972, Vol.IV - National Oceanic & Atmospheric Administration Program and U.S. Naval Research Laboratory Programs, pp.114.1-114.18

U.S. Navy, Naval Research Lab., Washington DC 20375
January 1972, 18 pages

CCRS NO. 1033391

The construction of a large gas-fueled power generation plant, from which thermal waste water is discharged into a shallow estuary (Trinity Bay) has provided an opportunity to address a specific problem : that is, to determine the impact of the thermal discharge on the bay. The bay and generation plant are well suited to the study, as both physical and mathematical hydraulic/thermal computer models of the bay are available. Also base-line data has been collected prior to and during the operation of the generation facility.

Specific objectives for data to study the power plant effluent are:
a) To evaluate the application of a two-dimensional mathematical model to the analysis of the thermal discharge, specifically, to verify the capability of the math. model in predicting the temperature distribution of Trinity Bay in the vicinity of the water outfall.
b) To compare the outputs of the Army Corps of Engineers physical model of Gelveston-Trinity Bay and the mathematical models to the analysis of the thermal discharge plume characteristics.
c) To determine the heating effects of the discharge on key aquatic species specifically, the effects, if any, on "Ruppia maritima", a bottom grass that covers approximately 190 acres adjacent to the effluent outfall. The grass provides an important natural nursery for small shrimp, crabs, and young fish.
c) To evaluate the most effective balance between remote, in situ measurements and modeling in the determination of the discharge plume characteristics.

1.8.0. REMOTE SENSING OF SOIL AND GROUNDWATER POLLUTANTS

1.8.1. Airborne Remote Sensing
- Infrared Imagery
- Electromagnetic Frequencies

1.8.2. Satellite Data

1.8.3. Studies and Investigations

SECTION 1.8.1. AIRBORNE REMOTE SENSING

Infrared Imagery

Brereton, N.R./Downing, R.A.

Some Applications of Thermal Infrared Linescan in Water Resources

Water Services, Vol.79, No.949, p.91-96
March 1975, 6 pages

CCRS No.

The remote sensing method of thermal infrared linescan has been applied in several regional studies concerned with the large scale development of groundwater resources. These studies were conducted to detect the location of groundwater discharges from the Chalk aquifer into the sea and to assess whether groundwater abstraction from a well field had any effect on vegetation or moisture content of the soil. Sewage outfalls with known temperatures and discharges were used as controls. The method is unlikely to detect spring discharges smaller than 100 liters. Groundwater discharges to rivers can be detected if the temperature difference between surface water and groundwater is sufficient to create a recognizable thermal anomaly or if groundwater discharge is high enough to not be diluted by the surface water too rapidly. While the Thermal Infrared Linescan method was not suitable for small or diffuse groundwater flow, the method is most applicable for detection of temperature anomalies in large expanses of water which can not be economically surveyed from the ground. In coastal surveys, this technique may also be useful for studying the mixing of river and sea waters and for detecting pollution.

SECTION 1.8.1. AIRBORNE REMOTE SENSING

Infrared Imagery

Brooks, H.K./Ruth, B.C./Degner, J.D.

Basic Hydrologic and Remote Sensing Data for Selection of Sanitary Landfill Sites

Florida University, Gainesville, Department of Geology
April 5, 1977, 28 pages

N77-26587/4ST

Aerial photography and LANDSAT imagery were used in the analysis of the terrain west of the city of Daytona Beach. High altitude colour infrared (CIR) photography was used in conjunction with LANDSAT imagery to classify terrain elements that relate to soils and hydrologic units. Computer tapes containing data for the four spectral bands from LANDSAT imagery were processed on the Image 100 interactive multispectral image analysis system to produce map (themes) that depicted specific categories of land use.

SECTION 1.8.1. AIRBORNE REMOTE SENSING

Electromagnetic Frequencies

Benson, R.C./Glaccum, R.A.

Remote Assessment of Pollutants in Soil and Groundwaters

National Conference on Hazardous Material Risk Assessment, Disposal and Management, Miami Beach, Florida, April 25-27, 1979

Hazardous Material Risk Assessment, Disposal and Management, Abstract p.7 April 1979

CCRS No.

The rapid assessment of various pollutants, concentrated or dispersed in soils or groundwater, is often accomplished by utilizing a wide range of electromagnetic frequencies. Lower KHz frequencies provide a means of continously measuring subsurface resistivity, while higher MHz frequencies enable continuous reflection profiling of subsurface geohydrologic details. These techniques have assessed oil and PCBs, gasoline spills, organic landfill leachates, sewage effluents, and salt water intrusion. Electromagnetic frequencies have provided direct detection and mapping of pollutants and indirect assessment and evaluation of the natural setting. Determination of porosity, direction of local groundwater flow, soil horizons, geochemical and geohydrologic information, as well as continuity of impervious layers have been made. Application of these technologies provides a new "high resolution window" in which reconnaissance and detailed assessment of sites are obtained.

SECTION 1.8.2. SATELLITE DATA

Whiting, J.M.

The Effect of Groundwater Inflow on Evaporation from a Saline Lake

American Meteorological Society, Boston, Massachussetts, October 1977

Second Conference on Hydrometeorology, October 25-27, 1977, Toronto, Ontario
October 1977, 6 pages

CCRS No.

A ten-year study of the Hydrometeorology of Big Quill Lake in Saskatchewan, a saline prairie lake, has effectively used remote sensing to delineate groundwater inflow. The lake covers an area of 250 square kilometers, with the groundwater seeping through 4 square kilometers. The salinity of the lake water forces the fresher groundwater to the surface by convection and spreads the colder groundwater by diffusion over an area of 50 square kilometers. The magnitude, source and discharge rate were determined using thermal diffusivity from data supplied by infrared line scanning. Two thermal scans were made of the lake and the data extended to provide a seasonal index using LANDSAT computer compatible tapes. The seasonal thermal index was extended further using four shore-based climatological stations to provide areal evaporation data using modified Benman and diffusion equations.

SECTION 1.8.3. STUDIES AND INVESTIGATIONS

Cichowice, N.L./Pease, Jr., R.W./Stroller, P.J./Yeff, J.

Use of Remote Sensing Techniques in a Systematic Investigation of an Uncontrolled Hazardous Waste Site

The Mitre Corporation, Meterele Division, Bedford, Massachusetts 01730

Municipal Environmental Research Laboratory, Office of Research and Development, U.S. EPA, Cincinatti, Ohio 45268
September 1981

P682-103846

This report describes the use and evaluation of several remote sensing techniques in conjunction with direct sample collection in order to develop a systematic approach for subsurface investigations at uncontrolled hazardous waste sites. Remote sensing techniques (electrical resistivity, seismic refraction, ground-penetrating radar and metal detection) which may be integrated with more conventional methods of test drilling, installation of monitoring wells, and excavation for determining information such as the following:

- nature and extent of ground water contamination
- presence and number of buried drums
- topography and condition of bedrock
- costs and effectiveness of several abatement methods.

Both remote sensing and conventional sampling methods were used at an abandoned hazardous waste dump in Coventry, Rhode Island.

1.9.0. REMOTE SENSING OF ATMOSPHERIC POLLUTANTS

1.9.1. Airborne Remote Sensing
- Multispectral Imagery
- Integrating Nephelometer
- Light Detection and Ranging (LIDAR)

1.9.2. Ground Remote Sensing
- Laser Methods

1.9.3. Satellite Data

1.9.4. Studies and Investigation

SECTION 1.9.1. AIRBORNE REMOTE SENSING

Multispectral Imagery

Schott, J.R./Gaucher, D.W.

Aquatic and Terrestrial Surveys in the Vicinity of Power Plants Using Remote Sensing

Calspan Corporation, P.O. Box 235, Buffalo, N.Y. 14221
PB 273 463
April 1977, 66 pages

CCRS No. 2003318

This report discusses a program to assess the potentials of aerial "photometric" interpretation in evaluating thermal aquatic impact. The intent of the program was to see to what extent the reflectance properties of elements in the environment as measured from aerial photography could be related to the condition of the environment.

In studies around fossil-fueled power plants, selected sites were ranked to levels of air pollution induced stress based on field observation of foliage. The reflectances of these same areas were measured using Calspan's aerial photometric analysis techniques. Results of this program indicate that vegetative stress in a forested environment, as defined by field observations, can be related to reflectance signatures as measured from aerial imagery.

SECTION 1.9.1. AIRBORNE REMOTE SENSING

Integrating Nephelometer

Clarke, A.G.

The Characterization of Atmospheric Haze by Ground and Aerial Measurements

Remote Sensing and the Atmosphere, International Conference by the Remote Sensing Society in the University of Liverpool, 15-17 December, 1982

Technical Information Service, Canada Centre for Remote Sensing, 240 Bank Street, 5th Floor, Ottawa, Ontario K1A 0Y7
December 1982, 9 pages

CCRS No. 1038859

Some methods of assessing the influence of air pollution on atmospheric visibility are discussed. Routine meterological reports can be used to indicate the frequency of occurrence of haze at relative humidities well below 100%. Results for two stations in N. England are given. Point monitoring of optical scattering by atmospheric aerosols can conveniently be undertaken using the integrating nephelometer. Typical ground level values and vertical profiles of the scattering coefficient, obtained from an instrumented helicopter, are given. For the U.K., long range transport of polluted air from Europe during anticyclonic conditions is particularly important. The fine particles (<2.5μm) responsible for light scattering can be separated from coarser particles using dichotomous samplers. Results for the more concentrations and chemical compositions for two sites during haze conditions in summer 1982 are presented.

SECTION 1.9.1. AIRBORNE REMOTE SENSING

Light Detection and Ranging (LIDAR)

Butler, C.F./Shipley, S.T./Allan, R.J.

Investigation of Potential Differential Absorption LIDAR Techniques for Remote Sensing of Atmospheric Pollutants

Old Dominion Univ., Norfolk, VA., Dept. of Geophysical Science

National Aeronautics and Space Administration, Washington, D.C.

Technical Information Service, Canada Centre for Remote Sensing, 240 Bank Street, 5th Floor, Ottawa, Ontario K1A 0Y7
July 1981, 108 pages

CCRS No. 2004591

The NASA multipurpose differential absorption LIDAR (DIAL) system uses two high conversion efficiency dye lasers mounted rigidly on a supporting structure that also contains the transmitter, receiver, and data system. The DIAL system hardware design and data acquisition system are described. Timing diagrams, logic diagrams, and schematics, and the theory of operation of the control electronics are presented. Success in obtaining remote measurements of ozone profiles with an airborne system is reported and results are analyzed.

SECTION 1.9.1. AIRBORNE REMOTE SENSING

Light Detection and Ranging (LIDAR)

Hawley, J.G./Uthe, E.E.

Laser Remote Sensing Activities Associated with the Electric Power Research Institute's Plume Model Validation Project

Remote Sensing and the Atmosphere, International Conference by the Remote Sensing Society in the University of Liverpool, 15-17 December, 1982

Technical Information Service, Canada Centre for Remote Sensing, 240 Bank Street, 5th Floor, Ottawa, Ontario K1A 0Y7
December 1982

CCRS No. 1038860

The Electric Power Research Institute (EPRI) has in recent years funded the development of two LIDAR (Light Detection And Ranging) systems for remote sensing of plumes from tall stacks of electric power plants. One system is an aircraft-borne particulate (Mie) scatter LIDAR which operates at 1.06 and 0.532 μm. The other is an ultraviolet differential absorption LIDAR for remote measurement of sulfur dioxide. These systems and a commercially available ground-based Mie scatter LIDAR were used in a large multi-year, multi-site program to document plume behaviour within 20 km. of the stack.

SECTION 1.9.2. GROUND REMOTE SENSING

Laser Method

Dybdahl, A.W.

The Use of LIDAR for Emissions Source Opacity Determinations : Second Edition

National Enforcement Investigations Centre, Denver, Colorado, Report No. EPA-330/1-79-003-R

Technical Information Service, Canada Centre for Remote Sensing, 240 Bank Street, 5th Floor, Ottawa, Ontario K1A 0Y7
July 1981, 399 pages

CCRS No. 2004591

LIDAR, an acronym for Light Detection and Ranging, is a laser radar which can be used to measure the opacity of particulate emissions from stationary sources. Extensive test results support the promulgation of the LIDAR technique as an alternate method to Reference Method 9, that uses trained visible emissions observers. Three tests demonstrate LIDAR precision and accuracy: one using an aerosol chamber to generate a controlled particulate plume, the second using an optical generator to simulate LIDAR return signals, the third using fabricated screen targets of constant fixed opacity. Correlation of LIDAR opacity values and visible emissions observations was measured by the LIDAR - Reference Method 9 Collaborative Test. The Colorado Smoke Generator Test correlated LIDAR opacity with a calibrated in-stack transmissometer. Advantages of LIDAR over VEO's are the ability to measure opacity during darkness and independently of background contrast conditions, and also the LIDAR is not subject to time and endurance constraints. Requirements and procedures needed to facilitate routine use of LIDAR were developed.

SECTION 1.9.2. GROUND REMOTE SENSING

Laser Methods

Hawley, J.G.

Dual-Wavelength Laser Radar Probes for Air Pollutants

Laser Focus, March 1981, Technology

System Techniques Laboratory, SRI International, Menlo Park, CA
March 1981, 2 pages

CCRS No. 1037149

The need to measure the concentration and spatial distribution of atmospheric pollutants often can be satisfied with differential-absorption laser-radar DIAL for short. Because a large region can be probled with instruments situated in a remote location, DIAL is a powerful tool for atmospheric research. In this article, describes a particular system built at SRI International Inc. which has monitored sulfur diode in plumes emanating from fossil-fuel power plants. The work has been sponsored by the Electric Power Research Institute. DIAL system built at SRI International designed for remote measurements of SO_2, O_3 and NO_2 emitted by power plants. Range is 3 km.

SECTION 1.9.2. GROUND REMOTE SENSING

Laser Methods

Persson, U./Johansson, J./Marthinsson, B./Eng, S.T.

Ethylene Mass Flow Measurements with an Automatic CO_2 Laser Long-Path Absorption System

Applied Optics, a Publication of the Optical Society of America, Vol.21, No.24, 15 December 1982

The Authors are with Chalmers University of Technology, Department of Electrical Measurements, S-41296, Goteborg, Sweden
December 1982, 4 pages

CCRS No. 1037205

A computer controlled CO_2 laser long-path absorption system has been used in a field experiment to measure the total emission of ethylene from a petrochemical factory. The ethylene concentration was measured along eight measurement paths at different elevations. Simultaneously meteorological data were collected. From these data we have calculated the mass flow from the factory. The result of the calculations agree well with the value estimated at the factory using conventional methods.

SECTION 1.9.3. SATELLITE DATA

Burke, H.H./Bowley, C.J./Barnes, J.C.

Evaluation of the Spatial and Temporal Measurement Requirements of Remote Sensors for Monitoring Regional Air Pollution Episodes

Environmental Research and Technology, Inc., Concord, MA., Report No. NASA-CR-159092
July 1979, 65 pages

CCRS No. 2004591

The spatial and temporal measurement requirements of satellite sensors for monitoring regional air pollution episodes were evaluated. Use was made of two sets of data from the Sulfate Regional Experiment (SURE), which provided the first ground-based aerosol measurements from a regional-scale station network. The sulfate data were analyzed for two air pollution episode cases. The results of the analysis indicate that the key considerations required for episode mapping from satellite sensors are the following: (1) detection of sulfate levels exceeding 20 micro-g/cu m; (2) capability to view a broad area (of the order of 1,500 km swatch) because of regional extent of pollution episodes; (3) spatial resolution sufficient to detect variation in sulfate levels of greater than 10 micro-g/cu m over distances of the order of 50 to 75 km; (4) repeat coverage at least on a daily basis; and (5) satellite observations during the mid to late morning local time, when the sulfate levels have begun to increase after the early morning minimum levels, and convective-type cloud cover has not yet increased to the amount reached later in the afternoon. Analysis of the satellite imagery shows that convective clouds can obscure haze patterns. Additional parameters based on spectral analysis include wavelength and bandwidth requirements.

SECTION 1.9.3. SATELLITE DATA

Salop, J./Wakelyn, N.T./Levy, G.F./Middleton, E.M.

The Application of Forest Classification from LANDSAT Data as a Basis for Natural Hydrocarbon Emission Estimation and Photochemical Oxidant Model Simulations in Southeastern Virginia

Air Pollution Control Association Journal, Vol. 33, No.1, January 1983
January 1983, 5 pages

CCRS No. 1038778

The possible contribution by natural hydrocarbon emissions to the total ozone budget recorded in the Tidewater region of southeastern Virginia during the height of the summer period was examined. Natural sources investigated were limited to the primary HC emitters and most prevalent natural vegetation, the forests. Three forest types and their areal coverage were determined for Region VI of the Virginia State Air Pollution Control Board using remotely sensed data from LANDSAT, a NASA experimental earth resources satellite. Emission factors appropriate to the specific types (coniferous 0.24 x10^{13}, mixed 0.63 x 10^{13}, deciduous 1.92 x 10^{13} μg/h), derived from contemporary procedures, were applied to produce an overall regional emission rate of 2.79 x 10^{13} μg/h for natural non-methane hydrocarbons (NMHC). This rate was used with estimates of the anthropogenic NOx and NMHC loading as input into a photochemical box model. Additional HC loading on the order of that estimated to be produced by the natural forest communities was required in order to reach certain measured summer peak ozone levels as the computer simulation was unable to account for these measured episodic levels on the basis of the anthropogenic inventory alone.

SECTION 1.9.4. STUDIES AND INVESTIGATION

Casas, J.C./Campbell, S.A.

Data Reduction Analysis and Application Technique Development for Atmospheric Trace Gas Constituents Derived from Remote Sensors on Satellite or Airborne Platforms

Old Dominion Univ., Norfolk, VA., Dept. of Geophysical Sciences, National Aeronautics and Space Administration, Washington, D.C.
May 1981

CCRS No. 2004591

The applicability of the gas filter correlation radiometer (GFCR) to the measurement of trophospheric carbon monoxide gas was investigated. An assessment of the GFRC measurement system to a regional measurement program was conducted through extensive aircraft flight-testing of several versions of the GFRD. Investigative work in the following areas is described: flight test planning and co-ordination, acquisition of verfying CO measurements, determination and acquisition of supporting meteorological data requirements, and development of supporting computational software.

SECTION 1.9.4. STUDIES AND INVESTIGATION

Fredriksson, K./Hertz, H.

Two Years of Evaluation and Testing of a Mobile LIDAR System for Air Pollution Monitoring

Int. Laser Radar Conference, Proc., 11th Madison, WI, June 21-25, 1982
pp.47-54

U.S. NASA Scientific and Technical Information Br., Washington, D.C. 20546

National Swedish Environment Protection Board, Studsvik, S-611 82 Nykoping, Sweden
June 1982, 8 pages

CCRS No. 1037520

A national mobile LIDAR laboratory was developed in 1979 at the Chalmers University of Technology, which was then the base for research activities. The laser remote sensing was recently reviewed and the mobile LIDAR system was described in detail in a recent paper. When the construction of the mobile system was completed in 1980, an evaluation and development phase for the system and its application were began at the Research Department of the Env. Prot. Board. For a period of two years the system was further developed and operated at several field tests. The results of the field work were presented in national reports and in papers being prepared.

The emphasis on the work was to develop operational routines for the monitoring of NO_2, SO_2, O_3 and particulates, but the activities was also directed towards the future research in this field, including extensions of the DIAL technique to include other gaseous pollutants and also meteorological applications of the LIDAR techniques.

SECTION 1.9.4. STUDIES AND INVESTIGATION

Gregory, G.L./Lee, R.B./Mathis, J.J.Jr.

The 1979 Southeastern Virginia Urban Plume Study, Volume 1: Description of Experiments and Selected Aircraft Data

National Aeronautics and Space Administration, Hampton, VA., Langley Research Centre, Report No: NASA-TM-81860-V-1
February 1981, 72 pages

CCRS No. 2004591

The Southeastern Virginia Urban Plume Study (SEV-UPS) utilizes remote sensors and satallite platforms to monitor the Earth s environment and resources. SEV-UPS focuses on the application of specific remote sensors to the monitoring and study of specific air quality problems. The 1979 SEV-UPS field program was conducted with specific objectives: (1) to provide correlative data to evaluate the laser absorption spectrometer ozone remote sensors; (2) to demonstrate the utility of the sensor for the study of urban ozone problems; (3) to provide additional insights into air quality phenomena occuring in Southeastern Virginia; and (4) to compare measurement results of various in situ measurement platforms. The field program included monitoring from 12 surface stations, 4 aircraft, 2 tethered balloons, 2 radiosonde release sites, and numerous surface meteorological observations sites. The aircraft monitored O_3, NO, NO_x, Bscat, temperature, and dewpoint temperature.

SECTION 1.9.4. STUDIES AND INVESTIGATION

Hergert, W.F./Couner, W.D.

Instrumental Sensing of Stationary Source Emissions

Environmental Science & Technology, Vol.II, Number 10, October 1977, p.962-967

Environmental Protection Agency, Research Triangle Park, N.C. 27711 October 1977, 6 pages

CCRS No.

Several techniques have been developed that can measure the concentration and velocity of gaseous species and particulate opacity. The velocity measurement is needed so that a mass emission rate may be determined. In order to evaluate the accuracy, utility, and state of development of some of these techniques, a series of measurements have been conducted at coal-burning power plants. The results of remote measurements were compared with results of instack measurements made using the EPA reference methods. The techniques studied in these programs are:

- infrared gas-filter correlation radiometry (GFCR), for SO_2 concentration
- Fourier-transform infrared spectroscopy (FTIS), for SO_2 concentration
- ultraviolet matched-filter correlation spectroscopy (MFCS), for SO_2 concentration
- infrared and ultraviolet television (IRTV and UVTV), for velocity and SO_2 concentration
- infrared laser-Doppler velocimetry (LDV) for plume velocity
- visible laser radar (LIDAR), for plume opacity.

SECTION 1.9.4. STUDIES AND INVESTIGATION

Setzer, A.W.

The Study of Air Pollution Plumes with Imaging Techniques

Ph.D. Thesis, Purdue University, December 1982
December 1982, 136 pages

CCRS No. 1037224

This work examines the possibilities of atmospheric dispersion studies through the use of small scale images of air pollution plumes, particularly through the use of LANDSAT imagery. The major points are:

1) A historical description of the uses of imaging techniques in atmospheric and plume dispersion studies.
2) A review of dispersion theories used with smoke and air pollution photography.
3) A study of a plume (up to 200 km) spreading over the ocean and visible in LANDSAT images is developed. Sixteen cases of this plume indicated that its shape and length depend mainly on the wind speed. Long plumes were characteristic of winds stronger than 5 m/s and spread within an angle of 5° to 7.5°. An association with Reynolds' (1883) experiments is made in spite of a difference of six orders of magnitude between the length of the plumes in these two works. Pasquill's (1961) horizontal dispersion coefficients were within an expected variation when compared to the values measured from the images. Nevertheless, this variation is associated with limitations in the dispersion equation and in the dispersion coefficients.
4) A study of LANDSAT multispectral data showed that plumes over water have their own spectral signature and that they can be located with an unsupervised classification technique ("cluster").
5) The remote sensing of plumes is suggested as a variable tool for environmental problems such as acid rain and long-range transport of air pollutants. The use of existing (as well as future) satellite images is a virtually unexplored source of data for environmental studies.

SECTION II

GENERAL APPLICATIONS AND SENSOR METHODOLOGY

2.1.0. REVIEW PAPERS

SECTION 2.1.0. REVIEW PAPERS

Chandler, P.B.

Aerial and Orbital Remote Sensing of Water Quality

North American Rockwell Corporation
xxx 1971, 10 pages

CCRS No. 1004416

A basic problem encompassed under environmental pollution is that of monitoring water quality. Monitoring is a relatively broad term which may include such activities as detection, identification, tracing, and concentration determination. The study reported in this paper indicates that both aerial and orbital remote sensors can provide new tools and techniques for these activities. Advantages of remote sensors over conventional water quality monitoring methods include simultaneous broad areal coverage, rapid acquisition (with possibilities for real time access), and ease of synoptic coverage. Used as an adjunct to more conventional techniques, current air- and space-borne sensors have relative merits and disadvantages in comparison with one another. Additionally, there is a definite chronological order in the application of such sensors, in that a thorough aerial study must take place before an adequate satellite program can be developed. At North American Rockwell, the problem has been approached in this fashion: various airborne remote sensors operating in the visible, infrared, and microwave regions of the electromagnetic spectrum have been tested to determine their utility in monitoring such water quality factors as turbidity, algae location and concentration, distribution and characterization of thermal effluent, oil spillage and other surface contamination, vessel waste discharge, storm run-off, and water colour have been used to evaluate the ultimate feasibility of water quality monitoring from space.

SECTION 2.1.0. REVIEW PAPERS

Egan, W.G.

Optical Remote Sensing of the Sea - A Caribbean Example

Int. Symp. on Remote Sensing of Environment, Proc., 14th, Vol.1, April 22-30, 1980, San Jose, Costa Rica

Environmental Research Inst. of Michigan, Ann Arbor, Michigan

Research Department, Grumman Aerospace Corporation, Bethpage, New York 11714
April 23-30, 1980, pp.563-586

A review is presented of the optical remote sensing of sea properties: chlorophyll, turbidity, land-water boundaries, bathymetry, sea floor biota and oil slicks. The need for absolute calibrated measurements of these properties is emphasized, whereby bulk absorption and scattering properties of the atmosphere. Two atmospheric models are discussed (LOWSUN and Dave Radiative Transfer model) to permit correction for atmospheric effects. The Cox and Munk representation of sea surface wave slope probability is also considered for optical modeling of reflection from the sea surface.

Finally, an example of detailed ground calibration with sea surface and atmospheric modeling is presented. The region considered is in St. Thomas, U.S. Virgin Islands, where a region of the harbour was studied in detail optically and biologically, with multispectral imagery from both an aircraft and LANDSAT-1.

The "bottom line" is the quantitative relation of the imagery to biological and chemical processes occuring in the sea. These processes affect sea water optical absorption and scatter, caused by particulate and chemical loading of the sea.

SECTION 2.1.0. REVIEW PAPERS

Kish, T.

The Many Uses of Remote Sensing

Journal of the Water Pollution Control Federation, Vol.53, No.4, p.420-425, April 1981

Remote sensing capitalizes on the fact that incident energy striking an object may be transmitted, absorbed, reflected, emitted, or scattered, resulting in identification and measurement and environmental parameters. Measurements must be taken on the ground to obtain actual water quality parameters in conjunction with use of remote sensing pictures. This is because satellite- or airplane-borne sensors generally only detect qualitative differences, which must be quantified by calibration with actual water samples from the area in question. Sensing instrumentation includes photographic systems and scanning systems. Scanner systems differ from photographic systems in that incoming radiation is focussed on a detector which translates the radiation intensity into a corresponding electronic signal. The signal is then either displayed on a cathode ray tube or recorded on magnetic tape. Various parameters that are detectable with current equipment include chlorophyll A, turbidity and suspended sediments, dissolved oxygen, poisonous red tides, municipal, industrial and pulp/paper effluent discharges, oil spills and oil seeps, plugged leachate fields of septic tanks, sanitary waste disposal siting, drainage studies and flood evaluations, acid-iron industrial waste, water depths up to 27 meters, salmon spawning grounds, kelp beds, coastal aquatic vegetation mapping, aquatic vegetation infestations, ground water, tidal zone length, non-point-source pollution, robot water quality monitoring, pH, hazardous waste site leachates, salinity in estuaries, and forecasts run-off from mountain snow packs.

SECTION 2.1.0. REVIEW PAPERS

Melfi, S.H. et al

Remote Sensing Instrumentation as it Relates to Environmental Monitoring

Exact Data Unknown (1974)

U.S. Environmental Prote[illegible] Agency, National Environmental Research Centre, P.O. Box 15027, [illegible]egas, NE 8911
xxx 1974, 11 pages

CCRS No. 1008392

The U.S. Environmental Protection Agency has a requirement for monitoring the environment. The need for monitoring exists both for establishing environmental standards and for enforcing standards already in existence. In the past, the Agency has relied primarily on in-situ or contact type instrumentation. Because of the ever-increasing industrialization of this country, with its resultant insult to the environment leading to increased number and quantity of pollutants, the monitoring problem is becoming more difficult and complex. To meet the challenge of this increased monitoring requirement, the Agency is looking to more sophisticated techniques, including remote sensing instrumentation.

SECTION 2.1.0. REVIEW PAPERS

Stevenson, M.R./Miller, F.R./Kirkham, R.G.

Comparison of NOAA 3-4 VHRR Imagery and LANDSAT Multispectral Scanner Images with Marine Resources Measurements

Inter-Am. Tropical Tuna Commission, Scripps Inst. of Oceanography, La Jolla, CA 92037
December 1976, 121 pages

CCRS No. 1015909

A comparison of satellite-derived data with observations made aboard NMFS research vessel DAVID STARR JORDAN are discussed, particularly the procedures used for processing shipboard data. Meteorological conditions during the month-long cruise are reviewed. Unusually cloudy conditions prevailed over the survey area most of the time and seriously limited the number of useable satellite overpasses.

Additional results in the analysis of LANDSAT-1 MSS data over the GNP of California are given. Careful evaluation of MSS data showed the need for further software development. Computer programs were written to correct for image skew for both compressed and full resolution imagery. In keeping with the objective of developing the capability of using a multi-sensor approach to marine problems, a set of transformation equations were written which will provide for superimposition of various sensor data fields.

The Commission's participation in a co-operative coastal Zone Ocean Colour Experiment is also reviewed. Commission staff agreed to provide meteorological forecasting and field co-ordination and to evaluate VHRRIR data collected during the experiment. The details of processing the raw VHRRIR data and sea truth data. Comments on meteorological conditions together with radiosonde soundings from the R/V MOANA WAVE are included.

SECTION 2.1.0. REVIEW PAPERS

Thomson, K.P.R.

Problems Associated with the Remote Sensing of Water Colour

Int. Commission for the Exploration of the Sea, 63rd, Statutory Meeting, October 1975, Montreal P.Q.

Canada Centre for Remote Sensing (DEMR), Ottawa K1A 0Y7
October 1975, 14 pages

CCRS No. 1006001

The objectives of this paper are to review in brief some essential considerations on the remote measurement of ocean colour, to discuss the practical implications of these measurements and to identify solutions to major problems.

The atmospheric models applied by various authors, and discussed briefly in this paper, indicate that surface level albedos can be estimated from satellite altitudes.

SECTION 2.1.0. REVIEW PAPERS

Vass, P.A./Van Genderen, J.L.

Monitoring Environmental Pollution by Remote Sensing

International Symp. on Remote Sensing, 12th Annual, Proc., Vol.1,
April 20-26, 1978, ERIM, Ann Arbor, Michigan

Environment and Resources Consultancy, Fairey Surveys Ltd., Reform Road,
Maidenhead, Berkshire, England
April 1978, 16 pages

CCRS No. 1017420

During the past 20 years, the polluted environment has become one of the major concerns of industrial societies. Continued growth in industrial development and in wastes from an ever-increasing number of sources, together with the need to preserve nature in its many forms, have focussed attention on the burgeoning problems of environmental pollution and the demand for the early and reliable detection of vegetation stress caused by pollution, so that effective monitoring and control measures can be introduced. The paper outlines the various types of environmental pollution which may be studied by remote sensing. Also man's detrimental effect on the land as a result of his development activities is discussed; this is of particular relevance to developing countries. The role of different remote sensors such as airborne cameras (including panchromatic, colour, colour infrared and multiband systems), airborne thermal and multispectral line scanners, side looking radar and satellite imagery for the identification and monitoring of environmental pollutants and their effects will be evaluated.

SECTION 2.1.0. REVIEW PAPERS

Wezernak, C.T./Turner, R.E./Lyzenga, D.R.

Spectral Reflectance and Radiance Characteristics of Water Pollutants

Report No. NASA CR-2665
April 1976, 230 pages

Spectral reflectance characteristics of water pollutants and water bodies were compiled from existing literature. Radiance calculations were performed at satellite altitude for selected illumination angles and atmospheric conditions. The work described in this report was limited to the reflective portion of the spectrum between 0.40 micrometer to 1.0 micrometer. Information was included for the following general categories: (1) water bodies, (2) phytoplankton-chlorophyll, (3) suspended solids, (4) oil, (5) municipal effluents, and (6) industrial effluents. The amount of suitable material in the professional literature was found to be very limited.

2.2.0. MANAGEMENT/PROGRAMS

SECTION 2.2.0. MANAGEMENT/PROGRAMS

Ackerman, W.C.

Water Management ... General Report

Hydrological Sciences Bulletin, Vol.19, No.1, p.119-130

Illinois State Water Survey, Urbana
March 1974, 12 pages

Water management of both natural and man-made lakes is the most advanced step of scientific-engineering processes relating to these bodies of water. Programs of observation and analyses of how these complex lake systems operate would enable management to optimize the lake's behaviour so as to gain multiple benefits. In managing lakes, one must consider the on-site and off-site purposes to be served, all characteristics of the water body, and upstream and downstream effects. This report is a product of a July 1973 lake symposium focusing on the Hydrological-Hydraulic elements of geophysics. A state-of-the-art paper, it summarizes the major developments which have occurred in lake studies since the GARDA Symposium in 1966. The emphasis at that time was on Hydrological measurements and balances, directed at understanding and proper design, but with only a slight attention given to management aspects. Understanding is enhanced today, but all the questions at the time of GARDA are still important. Described are the areas in which principal advances have been made over the past seven years in the ability to manage lakes: (1) the international field year for the Great Lakes; (2) use of remote sensing as a tool for management; (3) the progress and status of numerical modelling for understanding, identification of data gaps, and for management; and (4) lake restoration as a deliberate attempt to reverse the processes of lake degradation.

SECTION 2.2.0. MANAGEMENT/PROGRAMS

Ahmed, S.A.

Detecting Water Pollution from Colour and Infrared Colour Aerial Photography

American Society of Photogrammetry, Proc., Little Rock, Arkansas, October 18-21, 1977, pp.1-17

ASP, Falls Church, VA 22044

The Trow Group Limited, 43 Baywood Road, Rexdale, Ontario M9V 3Y8 October 1977, 17 pages

CCRS No. 1019938

The paper briefly describes the use of remote sensing for detecting water pollution. The study was carried in two parts: laboratory work and field investigation. Simplified models were set up in the laboratory to see if the various chemicals were optically sensitive to photographic emulsions. The results proved to be rather encouraging. A field investigation of the Toronto Waterfront consisted of taking over 1,000 aerial photographs with different films and filters. The results indicated that a correlation between laboratory and fieldwork was not possible due to the complex nature of water pollution. In view of this, water pollution was divided into seven major categories and an optimum film and filter combination was found for each of the seven pollutant types.

SECTION 2.2.0. MANAGEMENT/PROGRAMS

Alfoldi, T.T.

Remote Sensing of Turbidity Phenomena in Lake St. Clair

Report to the Working Group on Abatement and Control of Pollution from Dredging Activities in the Great Lakes, November 1974

Applications Development, Canada Centre for Remote Sensing, Ottawa, Ontario K1A 0E4

A report on the remote sensing, analysis, to measure the relative contributions of dredging and ship passage activities to turbidity levels in Lake St. Clair, was conducted from March 1973 to July 1974 as a joint effort of the Marine Engineering Division, Public Works of Canada and the Canada Centre for Remote Sensing. CCRS was charged with the design and execution of airborne data acquisition and the ensuing image enhancement and analysis. Based on the observations made from available airborne and spaceborne data, ship traffic in Lake St. Clair is noted as causing more turbidity than a dredging operation at the test site. Also, the natural turbidity levels in Lake St. Clair are significantly higher than ship- or dredge-induced turbidity.

SECTION 2.2.0. MANAGEMENT/PROGRAMS

Burgess, F.J./James, W.P.

Airphoto Analysis of Ocean Outfall Dispersion

U.S. Environmental Protection Agency, 401 M St., S.W., Washington

Oregon State University, Dept. of Civil Engineering, Corvallis, OR 97331
June 1971, 298 pages

CCRS No. 1016515

Aerial photographs were taken of the ocean outfall waste plume at Newport, Oregon, during the summers of 1968, 1969, and the period extending from September 1970 through May 1971. Computerized techniques to analyze the photos were developed by combining the principles of photogrammetry and photo interpretation. This remote sensing system involving multispectral photography was utilized to calculate waste concentrations, water currents and diffusion coefficients.

Conventional boat sampling of the waste field was conducted concurrently with the photography during 1968 and 1969 field seasons. The waste concentration determined by the two methods were compared by matching ground co-ordinates.

Procedures were developed to evaluate proposed ocean outfall sites by using dye drops from an airplane. Diffusion coefficients and water current velocities were determined from aerial photography. A minimum of two photographic flights over the area were required to show the transport and spread of the dye patches.

Characteristic airphoto pattern elements are given for visual interpretation of the photography. Wind velocity, wave height and diffusion coefficients can be estimated from aerial photography.

SECTION 2.2.0. MANAGEMENT/PROGRAMS

Chase, P.E./Reed, L./Smith, V.E.

Utilization of ERTS-1 Data to Monitor and Classify Eutrophication of Inland Lakes

Symposium on Significant Results ... from ERTS-1, Proc., New Carrollton, MD, Vol.1-B, p.1597

NASA Goddard Space Flight Centre/NASA SP-327

Bendix Corp., Ann Arbor, Michigan
March 1973, 8 pages

CCRS No. 1003161

A technique is being developed for use of ERTS in estimating and monitoring trophic levels of inland lakes. Preliminary findings are that Michigan lakes and ponds of one acre or more are resolvable in bands 5, 6 and 7 of NASA MSS imagery under fair conditions (haze and 70% cloud cover). In processed imagery (CCT) smaller features, including water colour patterns, are evident within some lakes of 40 acres or more. Image distortion of lake size, shape, orientation, etc., is minimal; discrimination of lakes and ponds from various wetlands is good. Subsequent ERTS and aircraft imagery will be correlated with detailed ground truth of water colour and quality in eutrophic test lakes.

SECTION 2.2.0. MANAGEMENT/PROGRAMS

Charlton, J.A.

The Potential of Satellite and Aircraft Remote Sensing Techniques to Marine Pollution Monitoring

Mediterranean Pollution Conference, Palma, Majorca, September 24-27, 1979

Progress in Water Technology, 12(4) : 687-693, 1980
xxx 1980, 6 pages

Advances in pollution monitoring are anticipated as instruments and image interpretive techniques become more sophisticated. Current equipment includes passive instruments, which depend upon viewing UV to IR radiation from the earth's surface, and active instruments, which operate in the microwave region. Satellites designed to carry this equipment include NIMBUS 7, SEASAT A, LANDSAT Series (1, 2, and 3), NOAA-2 Series 3-5, TIROS-N, and the Metcosat Series. Data can be transmitted in digital form and is directly available from NOAA, NASA, or from the National Point of Contact Centres. Photographic data collected by the Satellites has been compared to known phenomena, and attempts have been made to develop theoretical algorithms from the data. Presently, only the upper water layers have been observed, but new instrumentation will discriminate between sediment and chlorophylls. Additional limiting factors include resolution and cloud interference.

SECTION 2.2.0. MANAGEMENT/PROGRAMS

Davis, E.M./Fosburg, W.J.

Application of Selected Methods of Remote Sensing for Detecting Carbonaceous Water Pollution

Remote Sensing and Water Resources Management, Proc., No.17, p.419

American Water Resources Association, Urbana, Illinois

University of Texas, Houston, Texas
June 1973, 14 pages

CCRS No. 1004074

A reach of the Houston Ship Channel in an area adjacent to Galveston Bay was investigated during three separate overflights correlated with ground truth sampling on the channel. Typical distribution of sampling stations is shown for the Channel area as well as Barbour's Cut in accompanying figure 1. Samples were analyzed for such conventional parameters as biochemical oxygen demand, chemical oxygen demand, total organic carbon, total inorganic carbon, turbidity, chlorophyll, pH, temperature, dissolved oxygen, and light penetration. Infrared analyses conducted on each sample included reflectance ATR analysis, carbon tetrachloride extraction of organics and subsequent scanning, and KBr evaporate analysis of CCl_4 extract concentrate. Imagery which was correlated with field and laboratory data developed from ground truth sampling included that obtained from aerial KA62 hardware, RC-8 metric camera systems and the RS-14 infrared scanner. These images were subjected to analysis by three film density gradient interpretation units; the Model 608 Isodensitracer, International Sensing System 12S, Multiband Camera Film Viewer, and Spatial Data Systems Datacolour instrumentation. An example of isodensitracer interpretation of imagery characteristics is figured. Data were then analyzed for correlations between imagery interpretation, as derived from the three instruments and laboratory infrared signatures and other pertinent field and laboratory analyses. Positive correlation of 0.882 between Datacolour°

readout and light penetrability is presented in figure 3. Correlation values obtained for some of the other parameters included organic carbon content (-0.596), turbidity (-0.631), chemical oxygen demand (-0.390), and chlorophyll (-0.872). Additionally, absorption bands generated by infrared spectrophotometric methods exhibited positive correlations between reflectance IR methodology in the 5.3μ band, isodensitracer readout, and turbidity. Inverse relationships were demonstrated in the 5.3μ band for COD, total carbon and dissolved oxygen. Data suggesting similar trends was found at the 3.4μ band.

SECTION 2.2.0. MANAGEMENT/PROGRAMS

Hoopes, J.A. et al

Application of Remote Sensing to the Determination of Mixing Zones for Effluents Discharged into Streams and Rivers

Multidisciplinary Research on the Application of Remote Sensing to Water Resources Problems, Chapter IV, p.38-63

University of Wisconsin, 500 Lincoln Drive, Madison, WI 53706
xxx 1972, 26 pages

CCRS No. 2003741

The research is directed toward development of an operational remote sensing water quality monitoring system. To accomplish this, five fundamental aspects of the problem have been under investigation during the past three years. These are: (1) development of practical and economical methods of obtaining, handling and analyzing remote sensing data; (2) determination of the correlation between remote-sensed imagery and actual water quality parameters; (3) determination of the optimal technique for monitoring specific water pollution parameters and for evaluating the reliability with which this can be accomplished; (4) determination of the extent of masking due to depth of penetration, bottom effects, and film development techniques to eliminate or minimize them; and (5) development of operational procedures which might be employed by a municipal, state or federal agency for the application of remote sensing to water quality monitoring, including space-generated data.

Satisfactory results, at least in a general sense, have been achieved for the first four aspects of the problems listed above. Primary emphasis is now being placed upon the fifth aspect of the problem, namely, the development of operational procedures. This requires, in some cases, refinements to the results obtained under the first four aspects of the problems.

SECTION 2.2.0. MANAGEMENT/PROGRAMS

Gordon, H.H./Nichols, M.M.

Skylab MSS Vs. Photography for Estuarine Water Colour Classification

Int. Symp. on Remote Sensing of Environment, 10th, Proc., Vol.1, October 6-10, 1975, Ann Arbor, MI 48107

Virginia Institute of Marine Science, Gloucester Point, VA 23062
October 1975, 15 pages

CCRS No. 1009250

A computer classification is performed on data from the Skylab multispectral scanner (S192) and Earth Terrain Camera (S190B) for the Rappahannock Estuary in the Chesapeake Bay. A comparison of results indicates a similar water class structure from colour film and MSS tapes, but a much better two-dimensional chart derived from the MSS.

SECTION 2.2.0. MANAGEMENT/PROGRAMS

Johnson, R.W./Harriss, R.C.

Remote Sensing for Water Quality and Biological Measurements in Coastal Waters

Photogrammetric Engineering and Remote Sensing, Vol.46, No.1, January 1980, pp.77-85

NASA Langley Research Centre, Hampton, VA 23665
January 1980, 9 pages

Results of experiments in the coastal zone indicate that pollution and oceanographic feature may be detected by remote sensing from aircraft and satellite platforms. Wide-area synoptic and/or repetitive coverage by remote sensors provides information that is not readily available by conventional shipboard measurement techniques. Remotely sensed data may be used to determine concentration and/or distribution of parameters such as particulates, chlorophyll a, temperature, salinity and phytoplankton diversity.

This assessment of the state-of-the-art indicates that remote sensing can make a major contribution to research areas identified by national advisory groups as high priority problems. Suggested research areas also illustrate the potential for unique contributions from remote sensing techniques when carefully combined with conventional oceanographic research methods. These research areas include (1) estuarine and continental shelf sediment transport dynamics, (2) transport and fate of marine pollutants, (3) marine phytoplankton dynamics, and (4) ocean fronts. Measurements of particulates, temperature, salinity, chlorophyll, and other parameters by remote sensing may extend and aid in the interpretation of detailed shipboard investigations, thus providing more comprehensive research program results.

SECTION 2.2.0. MANAGEMENT/PROGRAMS

Lane, R.K.

Photography and Other Remote Sensing of Water Pollution and Pollution Control
xxx 1970, 2 pages

Biosphere, collections, surface bloom, data collection, distribution of pollutants, aircraft remote sensing, surface waters, film cameras, wind, effluents, oil spills, rivers, lakes, oil pollution, sediments, Chedabucto, meteorological, detection of energy and surface oil flows can be recorded using suitable filters. A thorough water quality survey could result from perfection of specific photographic and spectral measuring techniques.

SECTION 2.2.0. MANAGEMENT/PROGRAMS

Lind, A.O.

Application of ERTS Imagery to Environmental Studies of Lake Champlain.

Third Earth Resources Technology Satellite-1, Symposium, Vol.1 : Technical Presentation, Section II, NASA SP-351, Proc., December 10-14, 1973, Washington D.C., p.1189-1196
xxx 1974, 8 pages

ERTS imagery has provided data relating to a number of environmental and limnological concerns such as water quality, lake flooding, and lake ice formation. Pollution plume data provided by ERTS was recently used in the Supreme Court case involving the states of Vermont and New York and a paper company. Flooding of lowland tracts has been a major concern due to a repetitive pattern of high lake levels, over the past three years, and ERTS imagery is being used to construct the first series of flood maps of the affected areas. Lake ice development and turbidity patterns have also been studied from ERTS, since these have significance for shore erosion studies.

SECTION 2.2.0. MANAGEMENT/PROGRAMS

Link, L.E.

Remote Sensing of Pollutant Discharges

ASCE National Convention, Meeting, Denver, CO., November 3-7, 1975

Americal Society of Civil Engineers, 345 E. 47th Street, New York, NY 10017, Meeting Reprint 2622

U.S. Army, Engineer Waterways Experiment Station, P.O. Box 631, Vicksburg, MS 39180
November 1975, 32 pages

CCRS No. 1018621

Computerized models provide excellent tools for evaluation of the water quality of a river basin. The application of models that simulate water quality requires knowledge of the location, type, and concentration of pollutant discharges into the stream or river basin.

The purpose of this study was to evaluate by quantitative simulation the capabilities of current photographic remote sensing techniques for detecting and identifying pollutant discharges.

The first portion of this paper presents a computerized mathematical model that provides a quantitative means of evaluating and comparing the capabilities of photographic remote sensing techniques for application to the pollutant problem. This general analysis capability did not exist prior to the model development. The second portion of the paper concerns application of the model to detect and identify pollutant discharges.

SECTION 2.2.0. MANAGEMENT/PROGRAMS

Lo, C.P.

Photographic Analysis of Water Quality Changes

Photogrammetric Engineering and Remote Sensing, Vol.42, No.3, March 1976

University of Georgia, Athens, GA 30602
March 1976, 7 pages

CCRS No. 1011136

Black-and-white aerial photography for 1956 and true-colour aerial transparencies for 1975 at 1:10,000 scale are used to study the impact of a changing environment on the water quality of Rambler Channel in Hong Kong. The extensive reclamation in the area undertaken by the Government has significantly transformed the land use of the coastal areas and inevitably has led to man-made pollution of the sea-water. The aerial photography has been found to be an efficient tool in detecting sources of pollution and in identifying the types of polluting substances, especially with the aid of the true-colour transparencies. All these are shown on two maps prepared directly from the aerial photographs with the aid of a Zoom Transfer Scope.

SECTION 2.2.0. MANAGEMENT/PROGRAMS

Lundquist, C.E.

Applied Remote Sensing of Water Pollution

Remote Sensing of Earth Resources, 2nd, Annual Conf., Tullahoma, Tenn., March 26-28, 1973, p.112

F. Shahrokhi, Edited, University of Tennessee, Space Inst.

Altair Remote Sensing SA, Lucerne, Switzerland
March 1973, 15 pages

CCRS No. 1003508

For effective management of water resources there is an urgent need for reliable synoptic information of water conditions in whole aquatic systems. This paper deals with an aerial continuous-strip multiband photographic system that provides new, often unique advantages for acquisition and processing of data having significance in water pollution control. By use of narrower spectral bands, as low as about 1 nanometer, than has been possible previously in conventional multispectral photography, detection and measurement of dissolved and suspended substances can be accomplished both quantitatively and qualitatively. In order to present the system in a concise form, this contribution treats the matter practically and is not burdened with exhaustive theoretical proof.

SECTION 2.2.0. MANAGEMENT/PROGRAMS

McCammon, H.

Sensor Utilization in New England

In : Proceedings of Conference on Environmental Quality Sensors, 2nd, National Environmental Research Centre, Las Vegas, Nevada, October 10-11, 1973, Section IX
December 1973, 5 pages

Use of remote sensing could provide a beneficial overview of New England's varied environmental problems, such as thermal plumes from power plants, air emissions and effluents from isolated rural industrial pockets, run-off and Heat Island build-up from congested urban-industrial areas, mining and ocean dumping operations, eutrophication in lakes and estuaries and rural community development. Infrared detection with resolution to 1°C isotherms should be used on overflights of the 49 major power plants to document the extent of thermal plumes. Sludge blankets formed in rivers and lakes adjacent to pulp and paper mills, as well as oil spills from petroleum terminals and storage areas, could be detected and quantified using remote sensing, and monitoring of particulate emissions and metal wastes could be improved. Aerial surveys could improve knowledge of non-point pollution sources, changes in effluents as secondary sewage treatment plants convert to tertiary, the effect of urban storm water run-off on river channels, the nature and depth of rural soil cover in relation to ability to assimilate septic tank drainage, and the impact of highway construction on watersheds. In land use planning and coastal zone management, aerial monitoring would be invaluable for evaluating soil profiles, geology, topography, vegetative cover, water resources, and salt water intrusion into groundwater aquifers.

SECTION 2.2.0. MANAGEMENT/PROGRAMS

McCoy, W.B./Lackie, T.H.

Water Pollution Surveillance Using Local Remote Sensing Equipment

Remote Sensing & Water Resources Management, Proc., No.17, p.325

American Water Resources Association, Urbana, Illinois

University of Saskatchewan, Saskatoon, Saskatchewan
June 1973, 6 pages

CCRS No. 1004066

Supplementary aerial photography has proved to be a useful tool in surveillance of water pollution. This is especially true in areas that are remote from the home base of governmental and commercial agencies offering services in this field. Techniques for securing imagery are well established and use of locally available light aircraft, adapted to serve as platforms for vertical photography, has proved to be technically and economically feasible. The 70mm Hasselblad camera set on specially designed mounts have provided excellent vertical imagery (including capability for multi-spectral work); and as techniques for quantitative interpretation of air photos are available, they will significantly increase the value of this method of water pollution surveillance.

SECTION 2.2.0. MANAGEMENT/PROGRAMS

Miller, S.F.

Remote Sensing of Red Tides

NASA Contract NAS 9-11870 Third Quarterly Report

University of West Florida, Pensacola, FL 32504
N76-25639
xxx 1976, 9 pages

CCRS No. 2002996

Red tides as an environmental and health problem have been documented in terms of historical and scientific literature. The environmental factors which contribute to Red Tide outbreaks have been discussed in detail, especially those with remote sensing applicability. The purpose now becomes one of determining which factors are feasible and most important to monitor. A matrix is being compiled which presents the environmental problem, resolution desired, most feasible sensors, range and resolution of these sensors, and a recommended sensor for each environmental parameter. This completed matrix will be included in the final report to NASA.

The Florida Department of Natural Resources has been recommended as the most capable agency to do the ground-truth research and direct remote sensing studies of the Red Tide problem.

SECTION 2.2.0. MANAGEMENT/PROGRAMS

Moore, W.C.

A Remote : Airborne Sensing Application to Water Pollution : Rideau River Drainage Basin

Masters Thesis Carleton University, Carleton University, Ottawa, Ontario xxx 1972, 27 pages

CCRS No. 1002093

This is a study of the technical feasibility of using airborne sensing as an investigating tool, a source of information and a permanent record (Roscoe 1960) of water pollution in the Rideau River drainage basin. The basin has been identified by the Economic Council of Canada (1969) as one of four basins in Eastern Ontario and Quebec significantly affected by water pollution. The Rideau basin is, therefore, a case for which the application of multispectral remote sensing techniques (Chapter 2) would make regional water pollution analysis practices much more meaningful and effective.

The twin-engined Skyvan aircraft operated by the Federal Department of Energy, Mines and Resources was used to acquire multispectral imagery from selected reaches of the Rideau River system in 1969. The overall objectives were to use this imagery for the following purposes:

a) to identify the extent and principal sources of water pollution in selected areas of the Rideau basin (Chapter 3 and 4);
b) to investigate the effectiveness of existing water pollution controls (Chapter 3); and
c) to examine a continuing practical operating capability for evaluating water quality changes in conjunction with a modified surface-sampling program in the Rideau basin (Chapter 5).

SECTION 2.2.0. MANAGEMENT/PROGRAMS

Mundy, J.C./Byrne, R.J./Welch, C.S./Gordon, H.H.
Boon, J.D. III

Application of Remote Sensing to Estuarine Problems

National Technical Information Service, Springfield, VA 22161
Annual Report No.3
December 1975, 168 pages

A variety of siting problems for the estuaries of the Lower Chesapeake Bay have been solved with cost-beneficial remote sensing techniques. Principal techniques used were repetitive 1 : 30,000 colour photography of dye-emitting buoys to map circulation patterns, and investigation of water colour boundaries via colour and colour infrared imagery to scale of 1 : 120,000. Problems solved included sewage outfall siting, shoreline preservation and enhancement, oil pollution risk assessment, and protection of shellfish beds from dredge operations.

SECTION 2.2.0. MANAGEMENT/PROGRAMS

Newmaier, G./Silvestro, F.

Measurement of Pollution Using Multiband and Colour Photography

New Horizons in Colour Aerial Photography, Seminar, Proc., New York, NY, June 9-11, 1969, pp.47-58

ASP 105 N. Virginia Ave., Falls Church, VA 22046

Cornell Aeronautical Lab., Inc., P.O. Box 235, Buffalo, NY 14221
June 1969, 12 pages

CCRS No. 1029891

Since 1964 we have been performing research to assess the application of remote sensing to water quality management. Special emphasis has been placed upon developing techniques and procedures based on spectral characteristics of various pollutant discharges. The purpose of this paper is to describe the approach we have taken and to demonstrates its measurement of pollution, both qualitatively and quantitatively.

In a program sponsored by the New York State Conservation Department, laboratory experiments were performed to determine the spectral characteristics of effluents from a paper industry, an oil industry, and a sewage plant. These data, along with theoretical studies, were used to extract the desired information from multiband aerial photographs taken over these discharges. The techniques employed allow estimation of pollution concentration in a number of cases.

SECTION 2.2.0. MANAGEMENT/PROGRAMS

Pirie, D.M.

California Coast Nearshore Processes Study

Army Engineer District ERTS

NTIS Springfield, VA
May 1973, 7 pages

Aircraft and seatruth data was collected simultaneously with three ERTS overpasses. Thermal patterns at the entrance to San Francisco Bay indicated complex mixing patterns resulting from tidal and nearshore currents. Dye released near the Russian River mouth was analyzed for riverine discharge and sediment transport.

SECTION 2.2.0. MANAGEMENT/PROGRAMS

Psuty, N.P./Allen, J.R.

Trend-Surface Analysis of Ocean Outfall Plumes

Photogrammetric Engineering, Vol.41, No.6, p.721-730

Rutgers - The State University, New Brunswick, NJ 08903
June 1975, 10 pages

CCRS No. 1005941

Measures of water quality associated with ocean outfall effluent plumes are approached through the use of standard photographs which are transformed into numerical data sets and handled by the statistical technique of trend-surface analysis. The solutions for the trend surfaces are presented and the residuals are analyzed to discern their covariation with water-quality variables. A high correlation is indicated for the measures of dissolved oxygen and the values derived from photographic images.

SECTION 2.2.0. MANAGEMENT/PROGRAMS

Roger, R.H.

Application of LANDSAT to the Surveillance and Control of Lake Eutrophication in the Great Lakes Basin

NASA Control NAS 5-20942 Type 3, March 1975 - September 1977

Bendix Corp., Aerospace Systems Division, 36215 State Road, Ann Arbor, MI 48107
September 1977, 181 pages

CCRS No. 1017312

The cost-benefits of using LANDSAT on an operational basis in the surveillance and control of Lake eutrophication was established. To accomplish this, LANDSAT data were used to derive maps and data graphics to support the EPA's study of lake eutrophication in Saginaw Bay and the States of Michigan and Wisconsin lake and watershed studies. These users provided ground truth and supported evaluation of cost-benefits of LANDSAT products. The significant results of the program included the demonstration of cost-effective systems for monitoring: trophic state of areas/scenes containing 200 or more lakes of 50 acres or larger; trophic state of the Great Lakes; and watershed land use required to predict pollutants in run-off.

SECTION 2.2.0. MANAGEMENT/PROGRAMS

Roger, R.H. et al

Environmental Monitoring from Spacecraft Data

Machine Processing of Remotely Sensed Data, Symp., West Lafayette in June 3-5, 1975

Laboratory for Applications of R/S, Purdue University, West Lafayette, IN 47907

IEEE Catalog No. 75 CH 1009-0-C

Bendix Aerospace Systems Division, Ann Arbor, MI
June 1975, 10 pages

CCRS No. 1005562

Section 208 of the Federal Water Pollution Control Act Amendments of 1972 provided the opportunity and funding to fight water pollution through the use of regional water quality planning. A common requirement of the 208 program is to develop a capability of predicting water quality in the rivers and lakes resulting from existing and potential land-use policies. To achieve this capability, the Ohio-Kentucky-Indiana (OKI) Regional Council of Governments is developing a deterministic model capable of predicting sediment and nutrient flow into the waterways. An essential input to OKI's model is an accurate map of land use within the watersheds. This information was obtained by OKI through the machine processing of LANDSAT-1 digital tapes. Computer tabulations were generated to obtain areas covered by each of 16 land-use categories were merged into 10 categories and mapped at a scale of 1 inch = 5,000 feet with detail to 0.44 hectares (1.1 acres) for the 2,700 square mile region. The map products and data were produced within a period of less than 90 days at a cost of $20,000, a significant improvement in dollars and time over conventional mapping techniques.

SECTION 2.2.0. MANAGEMENT/PROGRAMS

Strandberg, C.H.

Colour Aerial Photography for Water Supply and Pollution Control Reconnaissance

First Annual IRSI Sump., Proc., Vol.2, p. 123, 1969
IRSI Sacramento California

ITEK Data Analysis Centre, Alexandria, Virginia
xxx 1969, 9 pages

CCRS No. 1001354

Colour aerial photography offers unique advantages for detecting, identifying, and monitoring water pollution. The most important advantage is that colour by itself, may be a critical clue for identification.

If colour aerial photography is to be used effectively, we must be familiar with its strong points and, unfortunately, with its weaknesses. Special techniques are required for interpretation. These special techniques require special equipment because colour positive transparencies in roll form must usually be interpreted. Special techniques and perhaps equipment are required to measure or optically compare and assess the apparent colour of images. We must, in addition, use a common language to describe and report the apparent colour of images.

SECTION 2.2.0. MANAGEMENT/PROGRAMS

Talley, W.K.

Environmental Remote Sensing from Aircraft and Space

Int. Astronautical Federation, 27th Cong., Anaheim, CA, October 10, 1976

Int. Academy of Astronautics, 250 Rue Saint Jacques, 75005 Paris, France

U.S. Environmental Protection Agency, 401 M Street S.W., Washington DC 20460
October 1976, 7 pages

CCRS No. 1013907

Comprehensive environmental monitoring is absolutely necessary to accomplish the U.S. EPA's mandate "to reduce pollution to acceptable levels". The Agency uses a variety of monitoring methods; one of these, which has received increasing emphasis in the last few years, is remote sensing from aircraft and space. Recent application of remote sensing for monitoring measuring, and detecting environmentally significant information has demonstrated two advantages over more conventional methods: broadened perspective, and cost-effectiveness. This paper describes: the present EPA remote sensing program, the advantages of remote sensing, the direction of the program over the next 3-5 years, and the benefits expected to be derived from developing and utilizing remote sensing methods.

SECTION 2.2.0. MANAGEMENT/PROGRAMS

Usry, J.W./Hall, J.B.

National Aeronautics and Space Administration Operations - Remote Sensing Experiments in the New York Bight, April 7-17, 1975

NASA Langley Research Centre, Hampton, Virginia 23665

National Aeronautics & Space Administration, Washington, D.C. 20546
November 1975, 61 pages

CCRS No. 1010978

Six remote sensing experiments were conducted in the New York Bight between Apirl 7-17, 1975, to evaluate the role of NASA remote sensing technology to aid in monitoring ocean dumping. Twenty-two remote sensors were flown on the C-54, U-2, and C-130 NASA aircraft while the National Oceanic and Atmospheric Administration (NOAA) obtained concurrent in situ sea truth data using helicopters and surface platforms. The primary sensors included a radiometer/scatterometer (RADSCAT), Ocean Colour Scanner (OCS), Multichannel Ocean Colour Sensor (MOCS), four Hasselblad cameras, two Zeiss cameras, and an airborne multispectral photographic system (AMPS) containing four cameras, an Ebert spectrometer, a reconofax IV infrared (IR) scanner and a Precision Radiation Thermometer (PRT-5).

The purpose of this report is to document the operations performed by NASA in carrying out the six remote sensing experiments. Brief descriptions of the test site, aircraft platforms, experiments and supporting sensors are presented. The operations of each aircraft are discussed and aircraft flight lines, flight parameters, and data identification parameters are presented in figures and tables.

SECTION 2.2.0. MANAGEMENT/PROGRAMS

Van Domelan, J.F.

Photographic Remote Sensing - A Water Quality Management Tool

University Microfilms, Xerox University Microfilms, Ann Arbor, Michigan, U.S.A.

University Microfilm Limited, High Wycombe, England
xxx 1976, 220 pages

CCRS No. 1008935

Water quality investigations have assumed increasing importance in our society, as pollution levels have increased. Conventional, in situ water sampling techniques and the allied laboratory analysis methods are time consuming and costly, especially where detailed information is necessary for large water bodies. Photographic remote sensing techniques are being developed, at the University of Wisconsin and elsewhere, to measure water quality parameters, such as turbidity and suspended solids by correlating the amount of energy reflected from a water body with the magnitude of the water quality parameter. While these techniques have shown promise, under very limited specified illumination conditions (completely clear or completely overcast days), the problem of varying energy levels incident on the water body, and the subsequent amount of energy reflected from the water body under partial cloud cover, has not been adequately defined.

The author has developed, through the experimental work described in this thesis, a technique for arriving at the energy returning from the particulate matter in the water. This technique works, whether a spectroradiometer or photography is used, and under various illumination conditions. The technique compares the vertical component of upwelling energy from a water body to that from a standard reflectance panel. The ratio of the two has been defined as the total relative albedo (A_T). Relative albedoes exist for the bottom (A_B) and surface (A_S) of a water

volume. Total relative albedoes can be determined in the laboratory or the field through the use of photographic emulsions. To determine the relative volume albedo (A_V), the relative bottom albedo (A_B) and the relative surface albedo (A_S), are subtracted from the total relative albedo (A_T). The relative volume albedoes, whether determined in the laboratory (A'_V) or from the photographic emulsion (A''_V) have been shown in this thesis to be highly correlatable to the water quality parameter of turbidity. They have also been shown to correlate to total suspended and volatile solids on a limited geographic basis; as distinct types of solids yield quite different correlations. The critical questions of the return of energy, from: the bottom of a water volume and from surface films on a water body as well as scattered energy within the atmosphere, have also been treated and methods of determining the magnitudes of each have been presented.

Through the use of non-linear regression analysis, the specific form of the exponential equations has been determined which satisfy the collected data. The same type of analysis also allowed the selection of a predictive method for estimating the relative surface albedo of a water body under varying skylight conditions.

Small-format, hand-held aerial photography has been proven to be a viable technique for the gathering of <u>quantitative</u> water quality data.

SECTION 2.2.0. MANAGEMENT/PROGRAMS

Villemonte, J.R./Hoopes, J.A./Wu, D.S./Lillesand, T.M.

Remote Sensing in the Mixing Zone

Remote Sensing and Water Resources Management

1973 American Water Resources Association Symposium, Burlington, Ontario June 1973, 19 pages

The general objective of this report is to give an overview of project goals and activities to date, together with a conceptual discussion of the mixing zone definition and measurements associated therewith. It will be necessary to show the consequences of co-ordinating ground and aerial techniques and methods, in contrast to their inadequacies when separated. In addition, sufficient results will be presented to serve as indicators of the type of work accomplished and yet to evolve as the work proceeds. Three of the seven field sites will be used in order to cover a fairly wide spectrum of waste effluent situations indigenous to the industries and municipalities of Wisconsin. The central objective of the report was the study of the characteristics of dispersion and diffusion as the mechanisms by which pollutants are transported in natural river courses, with the view of providing additional data for the establishment of water quality guidelines and effluent outfall design protocols.

ADDENDUM FOR SECTION II

MANAGEMENT/PROGRAM

SECTION 2.2.0. MANAGEMENT/PROGRAMS

Alfoldi, T.T./Sorensen, B.M.

State-of-the-Art Survey of Oil Spill Detection, Tracking and Remote Sensing in Cold Climates

A Final Report Prepared for the Environmental Emergency Branch, Environmental Protection Service, Environment Canada, Ottawa, Ontario March 1983, 64 pages

CCRS No. 1038353

The detection and subsequent tracking of the fate of marine oil spills in cold climates is afforded by recent technological developments, as well as judicious use of the human visual system. A variety of buoys is now available for following the progress of oil on water, or in an ice-infested environment. Active, radio frequency transmitters and navigational systems will keep accurate track of the progress of these buoys. Airborne and, to a certain extent, satellite-borne sensor can be used to probe for oil on or under the water, or entrained in, or trapped under ice. From the more conventional camera systems, to the more sophisticated laser, radar and acoustic sensors, each has its own advantages in determining the existence, measuring the spatial distribution, or defining the type of oil that has been released into the environment.

ACKNOWLEDGEMENT

I wish to express my appreciation for guidance and support during the compilation of this reference system. Mrs. K. Bueckert and Mr. A. Fabro provided invaluable assistance in expediting the acquisition of materials. Mr. G.F. Tomlins of B.C. Research provided a practical perspective on the field and reference materials. Encouragement and guidance by Mr. N. Holman and Mr. M. Pomeroy were particularly important.

Grateful appreciation is also extended to the Technical Information Service of the Canada Centre for Remote Sensing (CCRS), Ottawa, Ontario, for providing materials.

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